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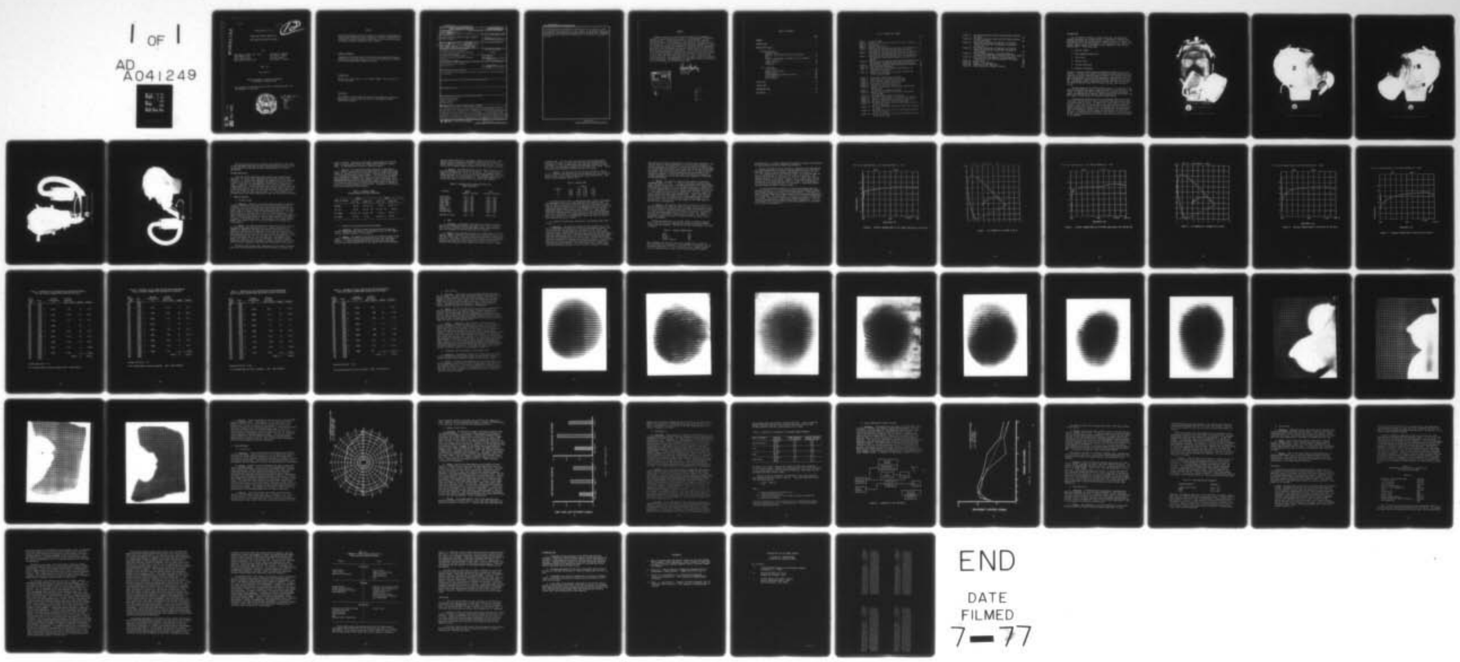

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USAARL Report 77-14

VISUAL AND OPTICAL ANALYSES OF XM-29 AND M-24 PROTECTIVE MASKS

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JUNE 1977

Final Report

US Army Aeromedical Research Laboratory
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UNITED STATES ARMY AEROMEDICAL RESEARCH LABORATORY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

USAARL was tasked to provide medical guidance and assessment relative to visual and optical aspects in the development of the XM-29 protective mask. In fulfillment of this responsibility, complete optical and visual tests have been completed on the new mask prior to its validation. To provide baseline and comparison information, identical optical testing was also performed on the M-24 aviator's protective mask, and visual performance testing was completed with the XM-29 mask, the M-24 mask, and unobstructed vision. Of the 13 optical and visual tests used, performance of the XM-29 mask was inferior to the M-24 mask on

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8 of them; equivalent performance was obtained with the two masks on 4 tests, while the XM-29 mask was better on 1 test. Several of the optical properties are unacceptable in the present design configuration of the XM-29 mask. Recommendations are made which should be considered prior to validation of a new protective mask.

SUMMARY

USAARL was tasked to provide medical guidance and assessment relative to visual and optical aspects in the development of the XM-29 protective mask. In fulfillment of this responsibility, complete optical and visual tests have been completed on the new mask prior to its validation. To provide baseline and comparison information, identical optical testing was also performed on the M-24 aviator's protective mask, and visual performance testing was completed with the XM-29 mask, the M-24 mask, and unobstructed vision. Of the 13 optical and visual tests used, performance of the XM-29 mask was inferior to the M-24 mask on 8 of them; equivalent performance was obtained with the two masks on 4 tests, while the XM-29 mask was better on 1 test. Several of the optical properties are unacceptable in the present design configuration of the XM-29 mask. Recommendations are made which should be considered prior to validation of a new protective mask.

Robert W. Bailey

ROBERT W. BAILEY
Colonel, MSC
Commanding

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INTRODUCTION

At the request of Chemical Systems Laboratory, the Aeromedical Research Laboratory was tasked by the U.S. Army Medical Research and Development Command to provide medical guidance relative to visual and optical aspects in the development of a new protective mask (XM-29). Six general areas requiring investigation were addressed in the original tasking letter. These areas were:

1. Optical Inserts
2. Mask Compatible Spectacles
3. Vision Test
4. Optical Tests
5. Foreign Technology
6. Domestic Technology

A report on optical inserts and mask compatible spectacles is in preparation. Information on domestic technology has been published by the Committee on Vision, National Research Council,[1] and foreign technology data are contained in Trip Reports prepared by and available from LTC Roy H. Rengstorff, Chemical Systems Laboratory, Aberdeen Proving Ground, MD. The present report presents data on visual and optical tests with the XM-29 protective mask, the M-24 protective mask, and unobscured vision.

The development of the XM-29 protective mask is in response to the published Required Operational Capability (ROC) for Protective Mask, ACN 11954. In concept, the XM-29 is designed as a universal mask which would, with appropriate components, replace the M17 and M17A1 Masks, the M9A1 Special Purpose Mask, and the M24 and M25A1 Masks.

The design of the mask consists of a unimolded construction fabricated from silicone which allows a transparent mask with minimal physical obstructions to vision. In theory, this would afford a much larger field of vision than in present masks which is of obvious advantage. However, quantity of vision must not be confused with quality of vision. Large curved optical surfaces, such as presented with the development mask, with negligible optical powers and aberrations are difficult to achieve. The optical design problems of the XM-29 are increased because of the distance between the eye and the mask surfaces and the thickness of the material.

FIGURE 1. Frontview of XM-29 Protective Mask

FIGURE 2. Right Sideview of XM-29 Protective Mask

FIGURE 3. LEFT SIDEVIEW OF XM-29 PROTECTIVE MASK

FIGURE 4. FRONTVIEW OF PROTECTIVE MASK M-24

FIGURE 5. SIDEVIEW OF PROTECTIVE MASK M-24

The tests and analyses here reported were undertaken to determine if the development mask had achieved an optimum optical design so that the new mask did not produce an unwarranted degradation in visual performance.

METHODS AND RESULTS

Since the visual requirements for aviators are considered most demanding, all optical tests performed on the XM-29 protective mask (Figures 1, 2, 3) were also completed, for comparison, on the M-24 mask (Figures 4, 5) which is the standard issue mask for aviators at this time. In addition, all psychophysical visual testing included three viewing conditions: wearing the XM-29 mask, wearing the M-24 mask, and unobstructed viewing. The same three male observers participated in all of the psychophysical tests, and only one mask size, medium, was evaluated since it was the only size available. It is most probable that different mask sizes would significantly alter the results here reported.

A. Optical Analyses

1. Prismatic Power

a. Apparatus. Measures of prismatic power are made by aligning a telescope reticle upon the center of a target containing a series of concentric circles of specified angular deviation and determining the extent that the reticle alignment has been shifted when the test transparent sample is placed in front of the telescope objective. For this test, an 8X Zeiss telescope with a cross hair reticle was used. Its objective aperture was reduced to 5 mm in order to maximize the depth of field. This was necessary due to the very high spherical and cylindrical power of the XM-29 mask lens. The concentric ring target, made at USAARL, was marked in units of 1/16 prism diopter to a maximum of 1 prism diopter.

b. Method. The detailed method for evaluating prismatic deviation followed the procedure specified in N.B.S. Special Publication 374, "Method for Determining the Resolving Power of Photographic Lenses." In addition to determining the magnitude of the deviation, direction was also noted (deviation to the left for the left eye was designated "out" while deviation to the right for the right eye was designated "out") and if the displacement was off the horizontal axis, the angular extent above (+) or below (-) this axis was estimated. Following standard convention, the results are displayed in terms of the base of the prism which is exactly opposite to the direction of deviation of the target.

The XM-29 and M-24 masks were supported on a wire frame of average adult male size and placed in front of the telescope to simulate four

angles of regard: looking straight ahead, looking about 30° left and right in the horizontal plane, and looking about 45° below straight ahead. An interpupillary distance of 65mm was assumed.

c. Results. The measured prismatic deviation is presented in Table 1 below. Federal Specification GGG-G-501b for goggle lenses and Commercial Standard CS159-49 for sunglass lenses set 1/16 prism diopter as the maximum acceptable prismatic power. For the XM-29, the average power exceeded this standard by a factor of 8.38, while for the M-24, the average power exceeded it by a factor of 5.94. In addition, MIL-L-00500064E (MU) specifies that the prismatic power in the lenses for the M-17 protective mask shall not exceed 0.38 prism diopter in the horizontal or 0.13 prism diopter in the vertical. Obviously, the XM-29 and M-24 values exceed this specification.

TABLE 1, PRISMATIC POWER
(PRISM DIOPTERS WITH BASE INDICATED)

ANGLE OF REGARD	XM-29		M-24	
	LEFT EYE	RIGHT EYE	LEFT EYE	RIGHT EYE
PRIMARY	.44 IN	.63 IN - 7½°	.50 IN	.38 IN - 5°
30° LEFT	.63 IN	.38 IN + 7½°	.31 IN - 12°	.38 IN
30° RIGHT	.38 IN + 10°	.56 IN - 10°	.31 IN	.25 IN - 5°
45° DOWN	.44 IN	.75 IN	.44 IN - 3°	.44 IN

2. Spherical and Cylindrical Refractive Power

a. Apparatus. Refractive power was measured with an American Optical Company Focimeter which is calibrated in units of 0.01 diopter and has a maximum range of ± 0.30 diopter.

b. Method. The spherical and cylindrical refractive power of the lenses of the M-24 and XM-29 were measured at nine loci (See Table 1, below.). In making these determinations the mask lens area being measured was always perpendicular to the optical axis of the Focimeter

and was firmly held by the ring support against the nosepiece. This method yields a conservative estimate or underestimate of the lens power, especially cylindrical which is higher when the lens is allowed to flex to its natural shape and moved to the normal wearing distance.

c. Results. The obtained values of lens power at each of the nine positions for both masks are given in Table 2. The average spherical power of the XM-29, at -.116 D, is just below the maximum allowable refractive power (± 1/8 D) specified in MIL-L-0050064E (MU); the cylindrical power of .127 D just exceeds it. The average spherical and cylindrical power of the M-24 lens falls within this standard.

TABLE 2, SPHERICAL AND CYLINDRICAL REFRACTIVE POWER (DIOPTERS)

Location	XM-29 (Sphere + Cylinder)	M-24 (Sphere + Cylinder)
Left Center	-.135 + .085	-.120 + .100
Right Center	-.110 + .100	-.060 + .080
Left Upper	-.125 + .160	-.070 + .090
Right Upper	-.160 + .205	-.080 + .040
Left Lower	-.135 + .105	-.110 + .135
Right Lower	-.095 + .150	-.020 + .040
Center	-.100 + .125	-.170 + .170
Extreme Left	-.085 + .080	-.070 + .070
Extreme Right	-.095 + .135	-.060 + .090
Average of 9 Loci	-.116 + .127	-.084 + .091

3. HAZE

a. Apparatus. Measurements were made with a Gardner Hazemeter, Model UX10, and Gardner Automatic Photometric Unit, Model Colorgard. The unit was calibrated using Gardner Model HG-1213 Haze Standards, which are traceable to the National Bureau of Standards.

b. Method. The procedure followed that of ASTM D1003-61 (1970), "Test for Haze and Luminous Transmittance of Transparent Plastics," and FTMS 406, Method 3022, "Luminous Transmittance and Haze of Transparent Plastics." Test samples consisted of four sections, each approximately two by three inches cut from a single XM-29 protective mask. Four locations were measured on each sample, providing a total of 16 haze

determinations. Care was taken to avoid areas that had observable scratches, abrasions, or other flaws that may have inflated the haze measurements. Prior to measurement each sample was washed with warm water and a mild detergent, swabbing with moistened lens tissue. Drying was accomplished by gently blotting with dry lens tissue.

c. Results. The observed haze values are presented in Table 3 below. It may be seen that haze varied considerably over the surface of the mask lens. Only a single location had a haze value below 4. The overall mean percentage haze was 5.59.

TABLE 3, PERCENT HAZE

	Sample			
Location	I	II	III	IV
A	4.36	5.08	5.03	8.12
B	6.38	4.81	5.92	5.96
C	3.80	4.19	4.75	8.15
D	5.11	4.34	6.02	7.39

Since the test for haze is a destructive test, directly corresponding measurements could not be made with the M-24 protective mask. In order to obtain an estimate of the M-24 haze, the laboratory was darkened and the entire mask was held in an appropriate position against the integrating sphere entrance port of the hazemeter with the door open. Measurements made at two locations were 1.2 and 1.5. These values accord with the much greater visible clarity of the M-24 lens compared with that of the XM-29. The values obtained for the XM-29 exceed that which is allowable in MIL-L-0050064E(MU), dated Jan 1973, for the M-17 mask, namely a maximum of 4% haze.

4. Spectral Transmission, Chromaticity, and Average Light Transmission.

a. Apparatus. The spectral transmission and chromaticity of the test samples were obtained by the rapid scan spectrometric method. The various components of the measuring instruments are as follow: The light source was a Macbeth daylight lamp with a 75-watt Westinghouse tungsten filament light bulb. The data acquisition unit was the Tektronix Rapid Scan Spectrometer (RSS) and Digital Processing Oscilloscope (DPO) with PDP 11/05 minicomputer and its accessories. The DPO has a signal acquisition capability, a display and a digital processor. The processor, which has the ability to digitize an acquired waveform, provides an interface with a minicomputer. The spectrometer uses a Czerny-Turner grating monochromator without an exit slit and is capable of scanning

the spectrum from 300 nm (ultraviolet) to 1100 nm (near infrared). The spectral output of the monochromator is focused onto the target of a vidicon tube where the spectrum is stored as an electrical charge image. An electron beam periodically scans across the vidicon target converting the charge image into an electronic signal that is, in turn, processed by the DPO. The entire optical computation can be achieved by the software programming. The average light transmission was measured by software averaging of the RSS and verified by a Macbeth T.D. 504 Transmission Densitometer.

b. Method. The execution steps for the spectral transmission measurement were as follow: (1) Obtain energy power spectrum without sample through RSS and store in DPO memory location B; (2) Obtain energy power spectrum transmitted through the sample and store in location C; (3) Obtain energy power spectrum of ambient (background) light and store in D; (4) Subtract D from B and C, divide C by B and store in location A. The computer program which was presented in a previous report[2] was used to execute the above steps automatically. Some of the end data points of the short wavelength portion of the spectrum were truncated for the computations of average light transmittance because of processing errors resulting from the weak output of the light source in this portion of the spectrum.

c. Results. The spectral transmission from 400 nm to 800 nm for the XM-29 and the M-24 masks are shown in Figures 6 and 8 respectively. Their corresponding CIE chromaticity coordinates and diagrams are shown in Figures 7 and 9. Spectral transmittance of an outsert furnished to us by the Mask Development Office is shown in Figure 10. Figure 11 is the spectral transmittance of XM-29 plus an outsert. The outsert is reportedly designed to be used in conjunction with the mask in cold weather environments.

Average transmittances are the mean values of spectral transmittances from the rapid scan spectrometric method and from the Macbeth transmission densitometer. Average transmittance measurements are shown in Table 4.

TABLE 4. AVERAGE TRANSMITTANCE

M-24	89%
XM-29	83%
Outsert	84%
XM-29 + Outsert	70%

MIL-L-0050064E (MU) specifies that light transmission for the M-17 lenses must equal or exceed 89%. While the M-24 is acceptable, the XM-29 transmittance does not meet this specification. Average transmittance is meaningful only if the curve across the spectral range is

relatively flat. In order to measure the degree of flatness or neutrality, the Judd Daylight Duplication Method was performed.

Tables 5 through 8 show the neutrality computed by the Judd Daylight Duplication Method and the spectral transmittance deviations (ref. MIL-V-43511A, "Visors, Flyer's, Helmet, Polycarbonate," section 4.3.7 pp 11). The average deviation for XM-29 is 3.50%. This indicates that the spectral distribution is relatively flat across the spectrum. The average deviation for the outsert alone is 3.30%. Again, this implies relative flatness of the sample. However, the average deviation of the combination of the XM-29 and the outsert is 6.98%. The average deviation for the M-24 protective mask is 1.62% which is lower than those of the XM-29 alone and XM-29 + outsert system.

It should be emphasized that all of these measurements were completed on new masks. It is expected that age and environmental exposure will degrade the optical clarity of the XM-29 material. This would, in effect, further reduce the average transmittance and spectral characteristics of the mask. Of course, this is true for all optical transparencies to a degree. The critical comparison is between age effects on the new coated silicone material and more standard optical materials. It is not known whether this type of comparison has been completed in a systematic and scientific investigation.

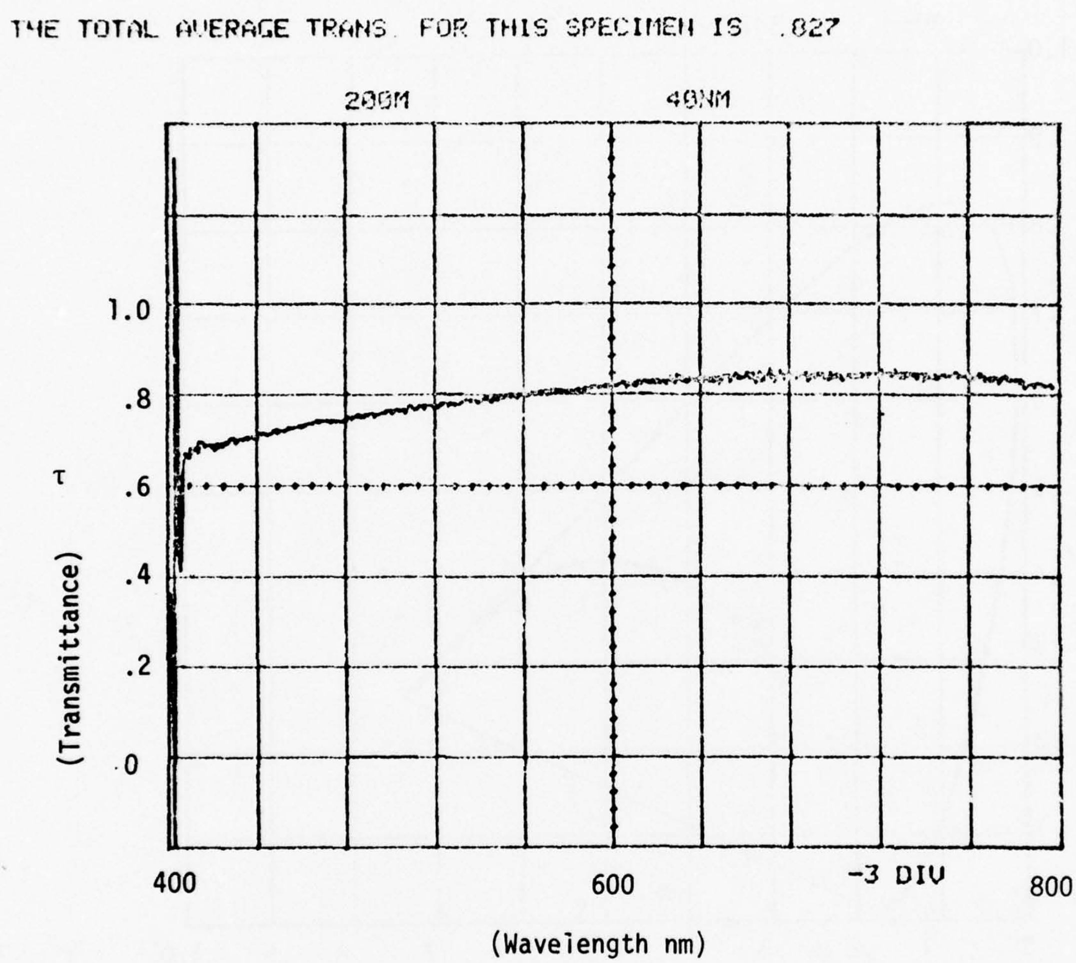

FIGURE 6. SPECTRAL TRANSMITTANCE OF XM-29 MASK (Wavelength 400-800 nm)

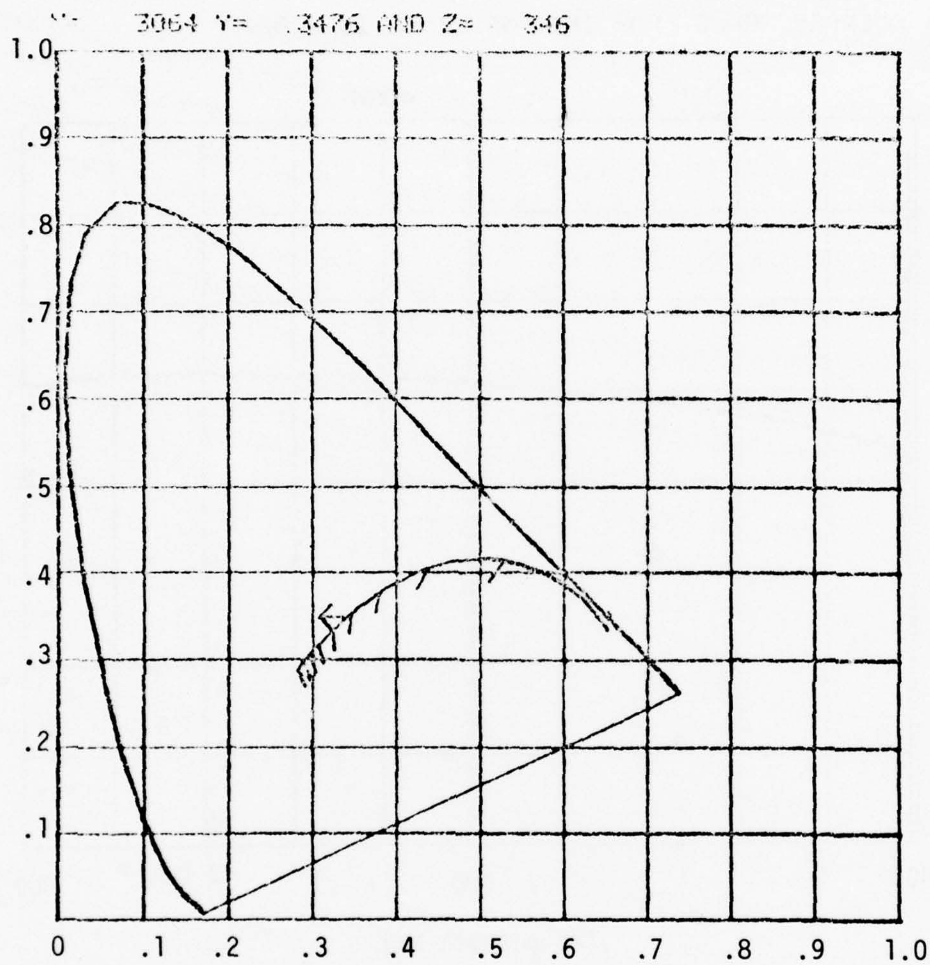

FIGURE 7. CIE CHROMATICITY DIAGRAM OF XM-29

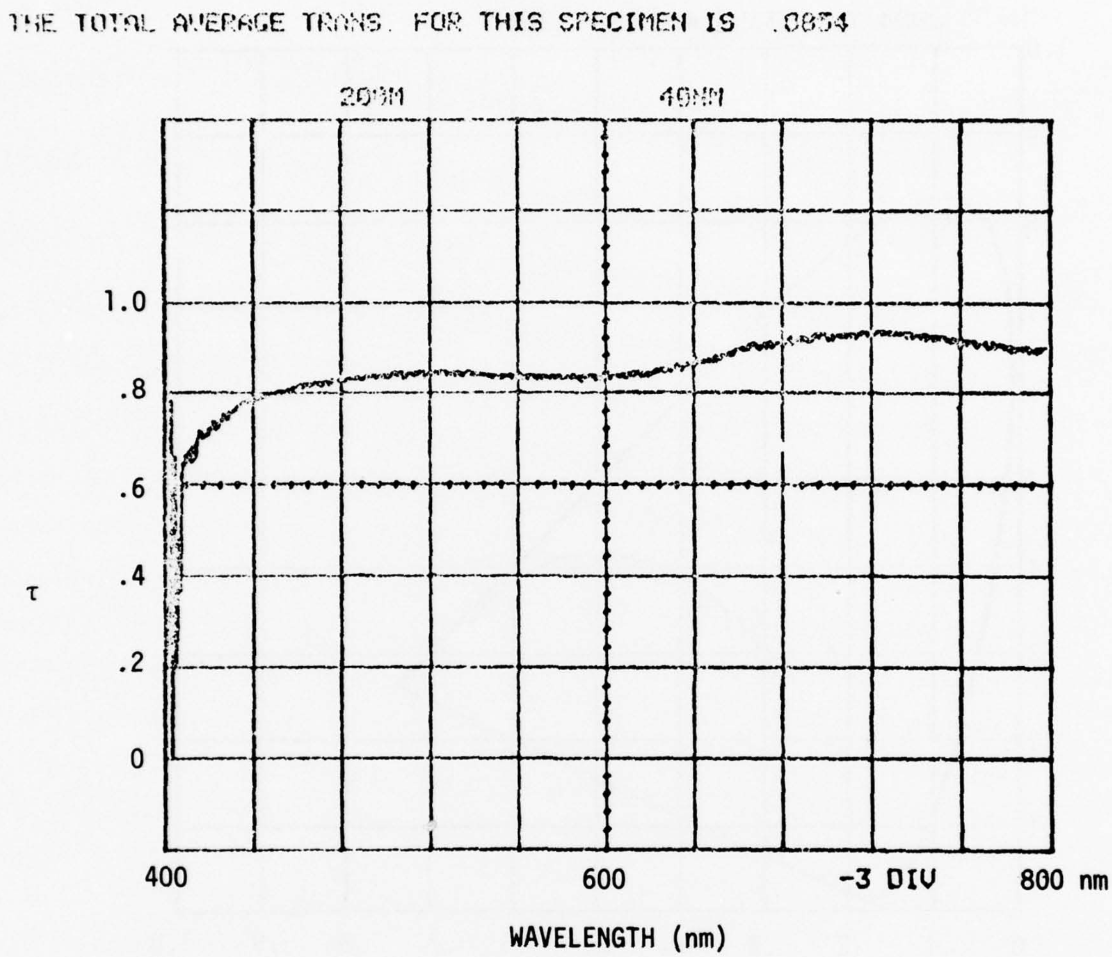

FIGURE 8. SPECTRAL TRANSMITTANCE OF M-24 MASK (Wavelength from 400-800 nm)

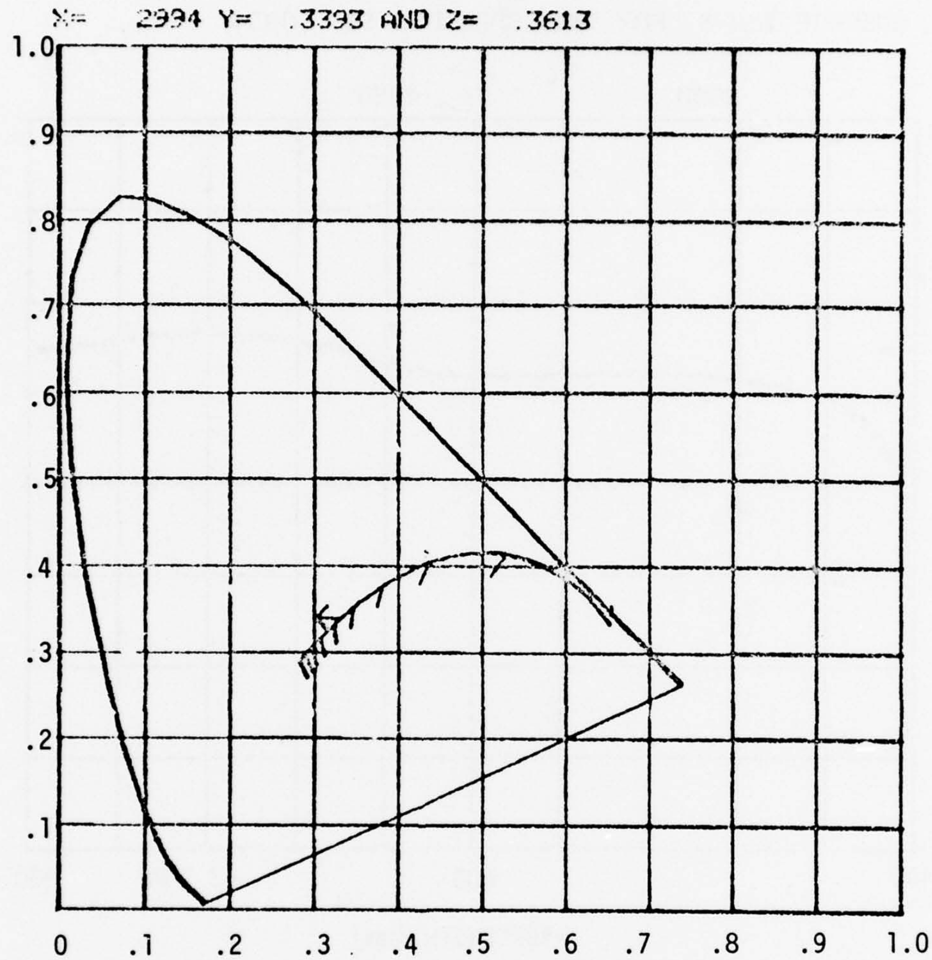

FIGURE 9. CIE CHROMATICITY DIAGRAM OF M-24 MASK

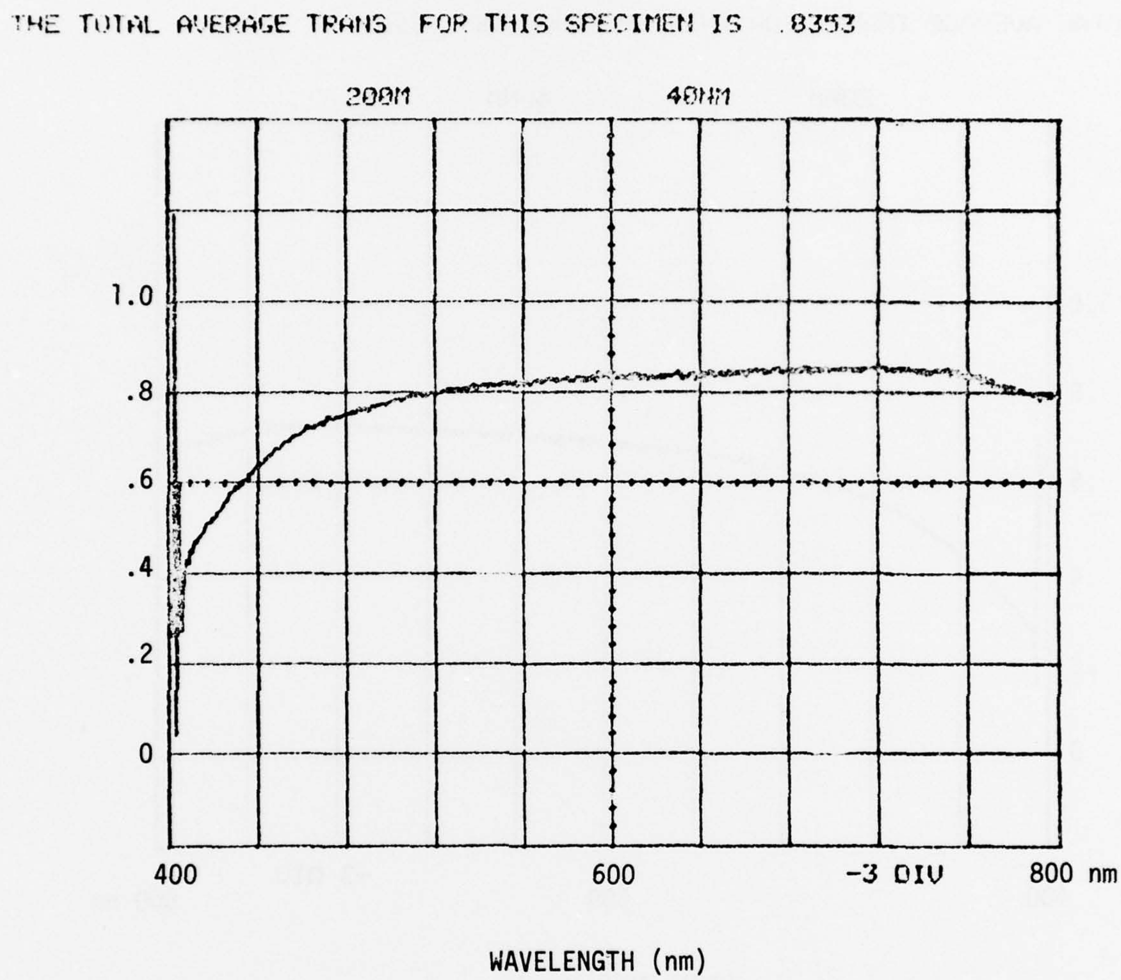

FIGURE 10. SPECTRAL TRANSMITTANCE OF AN OUTSERT FOR THE MASK

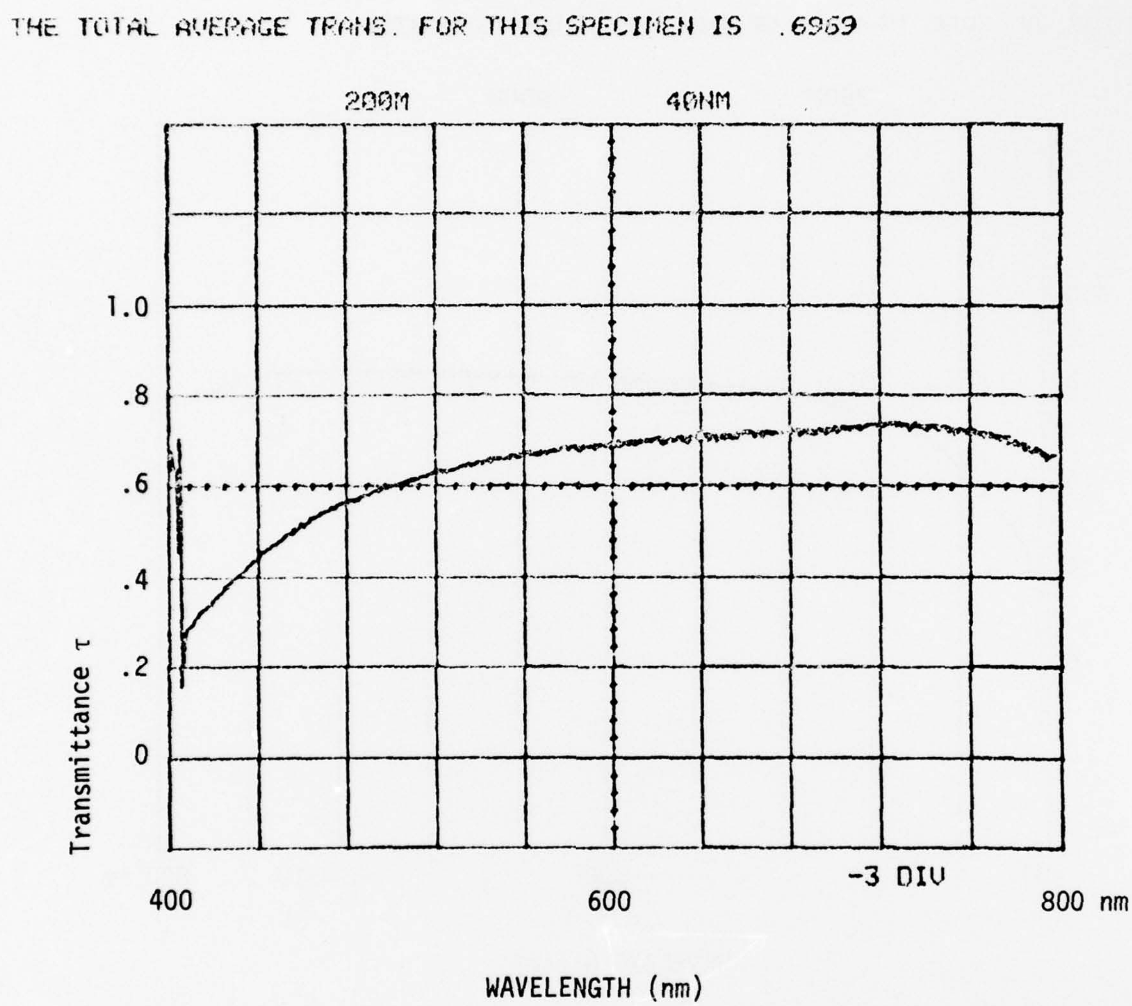

FIGURE 11. SPECTRAL TRANSMITTANCE OF XM-29 PLUS AN OUTSERT

TABLE 5. NEUTRALITY BY THE JUDD DAYLIGHT DUPLICATION METHOD AND THE SPECTRAL TRANSMITTANCE DEVIATION FOR XM-29

Wave-length (Mu)	Band T	n	Average Transmittance Tn	Percent Deviation 100 (1-Tn/Tc)	Weight	Product
430	.7032					
440	.7225					
450	.7272					
460	.7363	1	.7375	7.44	5	37.2
470	.7475					
480	.7572					
490	.7645	2	.7612	4.46	10	44.6
500	.7672					
510	.7742					
520	.7766	3	.7795	2.17	10	21.7
530	.7850					
540	.7925					
550	.7977	4	.7968	0	10	0
560	.8024					
570	.8081					
580	.8140	5	.8147	2.25	10	22.5
590	.8218					
600	.8285					
610	.8296	6	.8302	4.19	10	41.9
620	.8305					
630	.8427					
640	.8418	7	.8385	4.48	10	44.8
650	.8385					
660	.8413					
670	.8427	8	.8457	6.13	5	30.65
680	.8538					
690	.8469					
700	.8412	9	.8472	6.32	1	6.32
710	.8442					
720	.8521			TOTALS	71	249.67
730	.8467					

Average deviation = 3.5

This specimen meets military standards (Ref: MIL-V-43511A)

TABLE 6. NEUTRALITY BY THE JUDD DAYLIGHT DUPLICATION METHOD AND THE SPECTRAL TRANSMITTANCE DEVIATION OF AN OUTSERT

Wave-length (Mu)	Band T	n	Average Transmittance Tn	Percent Deviation 100 (1-Tn/Tc)	Weight	Product
430	.5954					
440	.6493					
450	.6898					
460	.7175	1	.7071	14.10	5	70.5
470	.7414					
480	.7596					
490	.7742	2	.7706	6.38	10	63.8
500	.7872					
510	.8000					
520	.8048	3	.8042	2.31	10	23.1
530	.8123					
540	.8220					
550	.8236	4	.8232	0	10	0
560	.8282					
570	.8327					
580	.8352	5	.8333	1.22	10	12.2
590	.8354					
600	.8352					
610	.8382	6	.8391	1.93	10	19.3
620	.8380					
630	.8495					
640	.8411	7	.8461	2.78	10	27.8
650	.8532					
660	.8513					
670	.8492	8	.8496	3.20	5	16.0
680	.8546					
690	.8498					
700	.8562	9	.8544	3.79	1	3.79
710	.8537					
720	.8580			TOTALS	71	236.49
730	.8589					

Average deviation = 3.3

This specimen meets military standards. (Ref: MIL-V-43511A)

TABLE 7. NEUTRALITY BY THE JUDD DAYLIGHT DUPLICATION METHOD AND THE SPECTRAL TRANSMITTANCE DEVIATION OF XM-29 PLUS OUTSERT

Wave-length (Mu)	Band T	n	Average Transmittance Tn	Percent Deviation 100 (1-Tn/Tc)	Weight	Product
430	.4061					
440	.4587					
450	.4933					
460	.5226	1	.5158	22.1	5	110.5
470	.5505					
480	.5718					
490	.5895	2	.5858	11.5	10	115.0
500	.6066					
510	.6176					
520	.6352	3	.6310	4.71	10	47.1
530	.6453					
540	.6545					
550	.6635	4	.6622	0	10	0
560	.6755					
570	.6753					
580	.6829	5	.6850	3.44	10	34.4
590	.6914					
600	.7014					
610	.7015	6	.7015	5.93	10	59.3
620	.7074					
630	.7097					
640	.7124	7	.7129	7.65	10	76.5
650	.7155					
660	.7210					
670	.7213	8	.7192	8.61	5	43.05
680	.7237					
690	.7228					
700	.7275	9	.7287	10.0	1	10.0
710	.7318					
720	.7356			TOTALS	71	495.85
730	.7400					

Average deviation = 6.98

This specimen meets military standards. (Ref: MIL-V-43511A)

TABLE 8. NEUTRALITY BY THE JUDD DAYLIGHT DUPLICATION METHOD AND THE SPECTRAL TRANSMITTANCE DEVIATION OF M-24 MASK

Wave-length (Mu)	Band T	n	Average Transmittance Tn	Percent Deviation 100 (1-Tn/Tc)	Weight	Product
430	.7656					
440	.7926					
450	.8106					
460	.8223	1	.8145	3.52	5	17.6
470	.8246					
480	.8320					
490	.8441	2	.8378	.769	10	7.69
500	.8398					
510	.8504					
520	.8485	3	.8466	.272	10	2.72
530	.8508					
540	.8461					
550	.8438	4	.8443	0	10	0
560	.8421					
570	.8395					
580	.8382	5	.8402	.485	10	4.85
590	.8390					
600	.8398					
610	.8411	6	.8465	.260	10	2.60
620	.8469					
630	.8575					
640	.8704	7	.8713	3.19	10	31.9
650	.8771					
660	.9023					
670	.9068	8	.9078	7.52	5	37.6
680	.9164					
690	.9286					
700	.9375	9	.9296	10.1	1	10.1
710	.9336					
720	.9378			Totals	71	115.06
730	.9407					

Average deviation = 1.62

This specimen meets military standards. (Ref: MIL-V-43511A)

5. Image Fidelity

a. Apparatus. Image fidelity was evaluated with the Ann Arbor optical tester. The New London - Ann Arbor optical tester with 60-line grating is manufactured by Ann Arbor Optical Company. The main components of the optical tester consist of a line grating, a miniature light source with variable voltage transformer, a lens and a plane mirror. The detailed optical schematic is shown in MIL-V-43511V. Camera equipment was used for photographic documentation.

b. Method. The test followed the steps outlined in MIL-V-43511A (Military Specification for Visors, Flyers, Helmet, Polycarbonate). Briefly, the procedure specifies that the optical distortion of the critical area of the sample shall be determined by inserting the sample with its surface normal to the line of sight into the testing apparatus. The results shall be subjectively compared with the distortion standards shown in Figure 1 of MIL-V-43511A (p 17).

c. Results. Photographic documentation of Ann Arbor Tester results are shown in Figures 12 through 18. Figure 12 shows the tester pattern grating without any sample interposed in the optical path. Notice that there is no distortion in this figure. All of the vertical lines are essentially parallel to each other and of good quality. Figures 13, 14 and 15 are grating patterns with the XM-29 samples inserted into the apparatus with three different orientations, i.e. right eye view, center and left eye view. Figures 16, 17 and 18 are for M-24 with the same three orientations, respectively. By the military specification (MIL-V-43511A, p 17) only Figures 17 and 18 pass the acceptance standards. Figures 13, 14, and 15 of the XM-29 resemble the unacceptable standard #9 published in the referenced specification and indicating the most severe degree of distortion. A portion of Figure 17 has a small degree of distortion shown as in unacceptable standard #7.

6. Distortion Test By ASTM Metric Grid Board Tester

a. Apparatus. The American Society for Testing Materials (ASTM) 1.8 cm grid board and photographic camera were employed to reveal any optical distortion which might be present in the two mask samples.

b. Method. The metric grid board was 90 cm from the camera and the protective mask was placed in front of the camera along the line of the presumed visual axis. The mask was oriented 45° to the left and to the right of the line of sight. The combination of the field of view from these two angles essentially covered most portions of the useful field of vision of the mask.

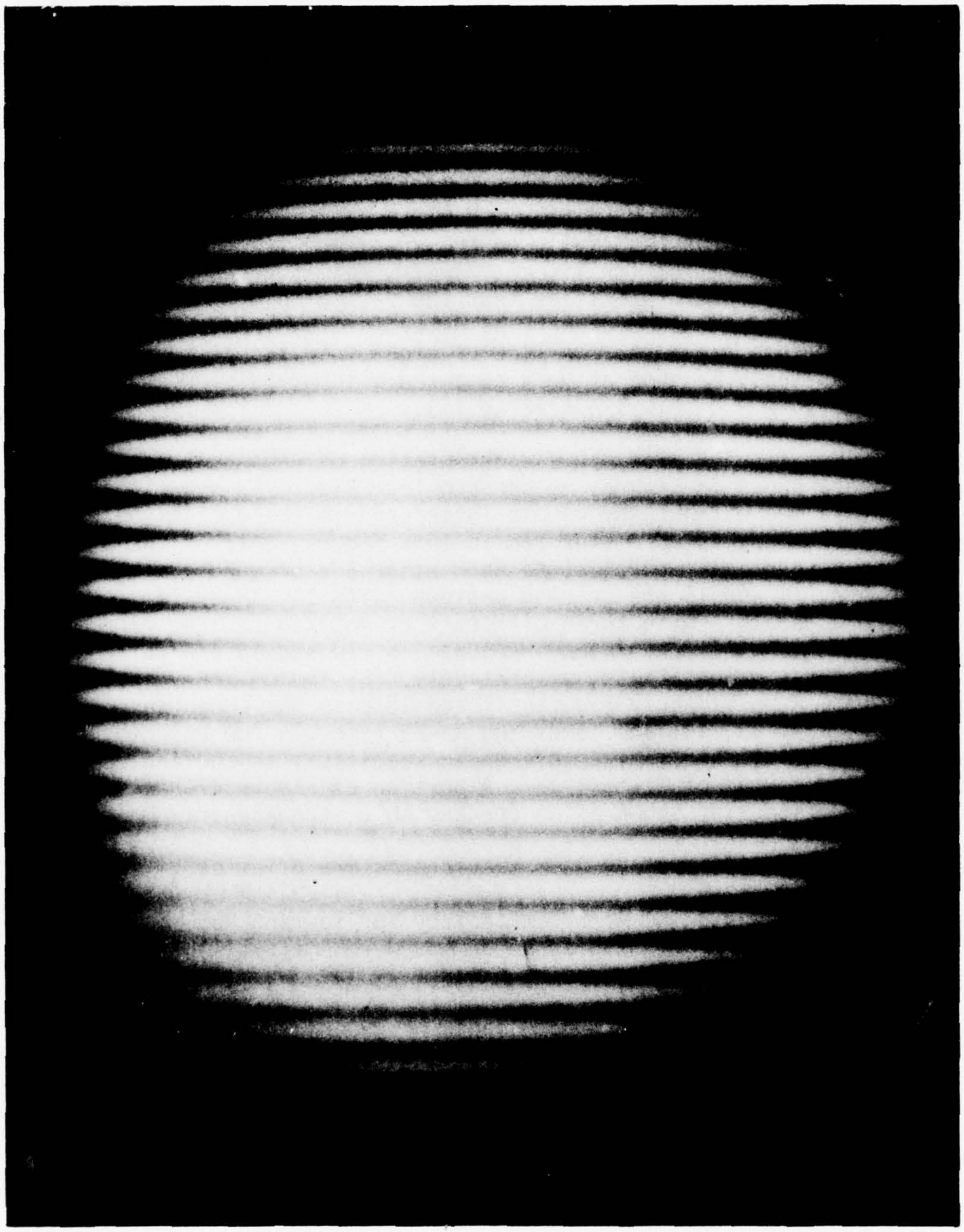

FIGURE 12. ANN ARBOR DISTORTION TESTER WITHOUT MASK

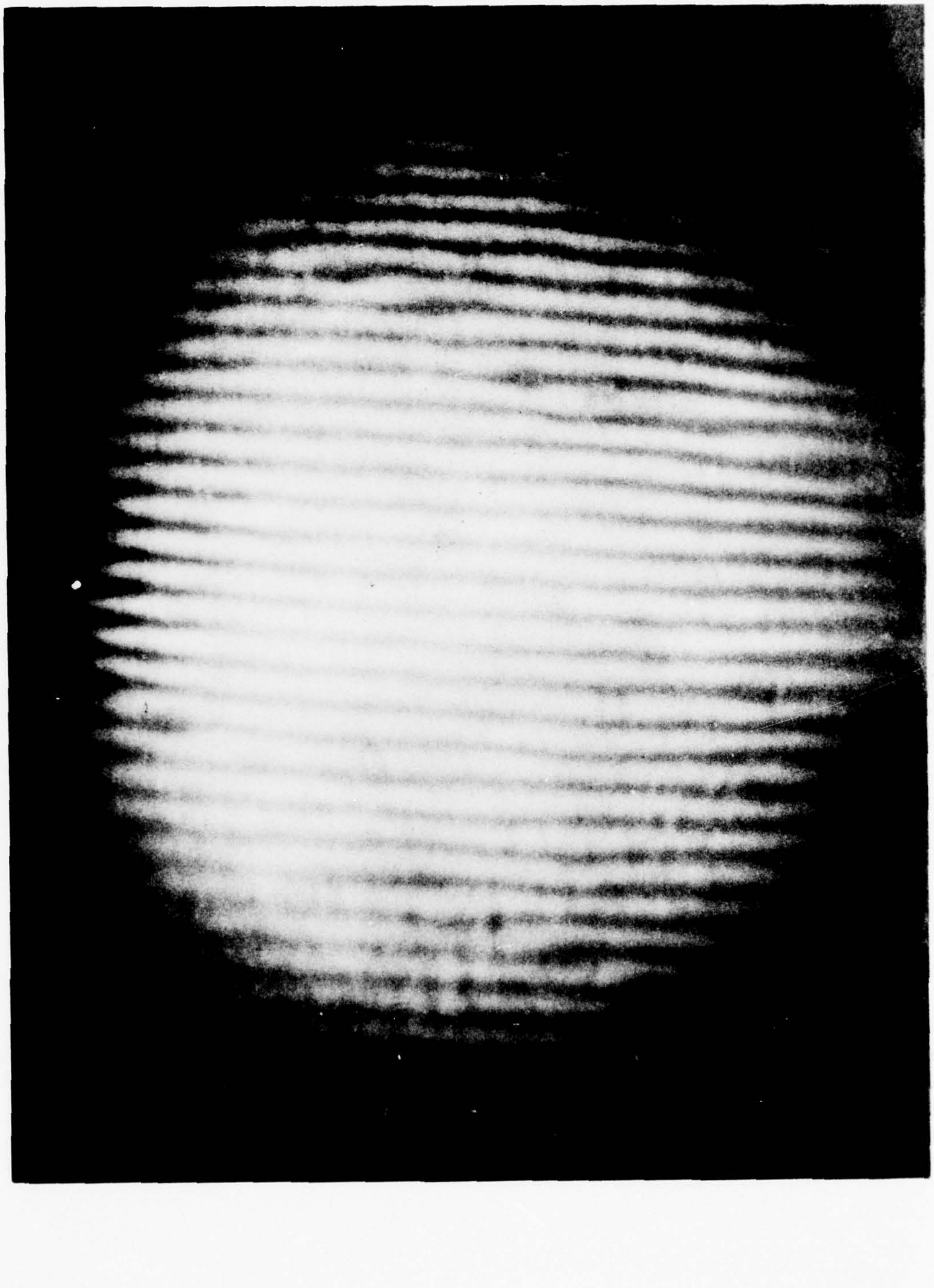

FIGURE 13. Ann Arbor Distortion Test With XM-29 Mask Oriented at 45° Right Angle

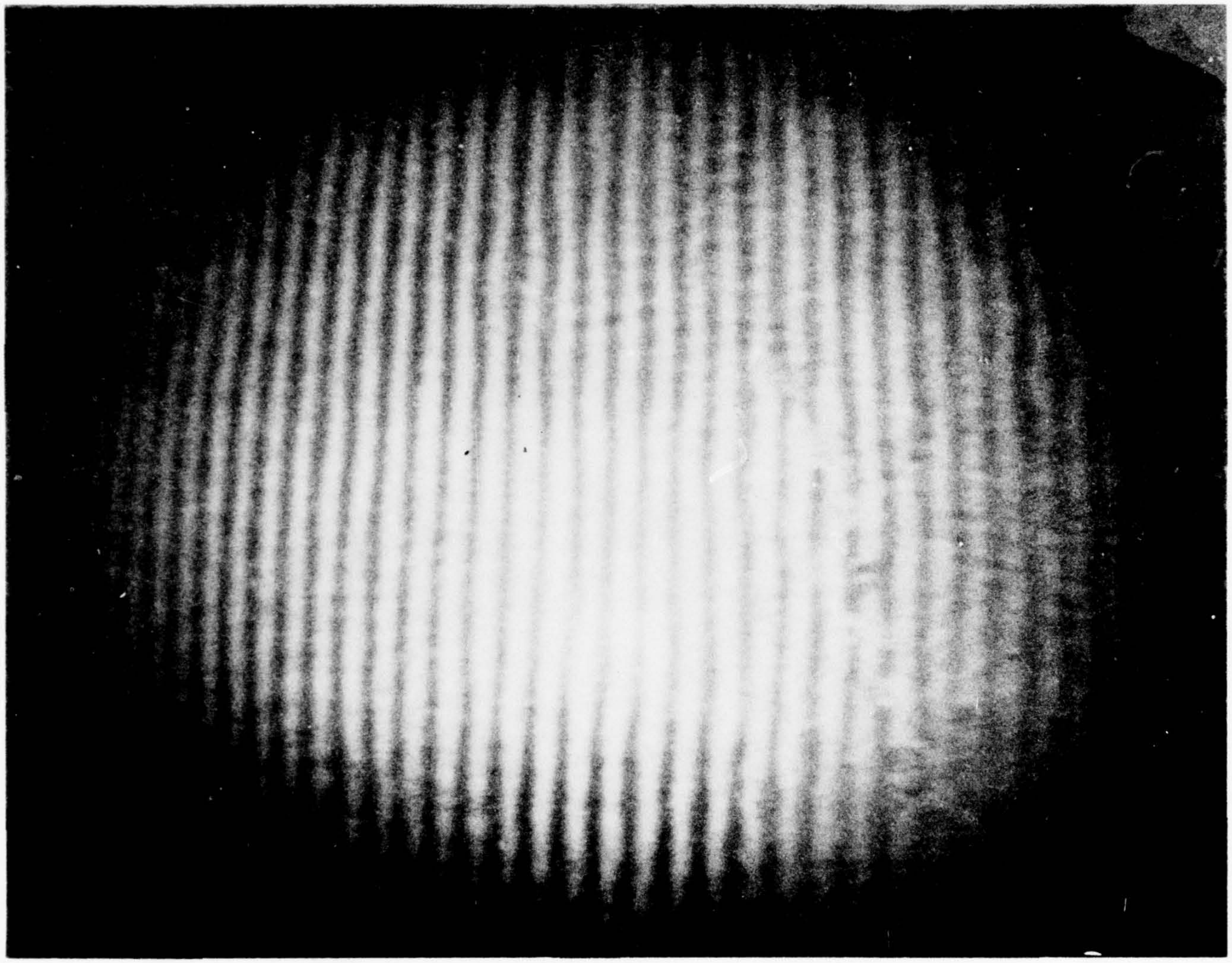

FIGURE 14. ANN ARBOR DISTORTION TESTER WITH XM-29 MASK ORIENTED AT CENTER

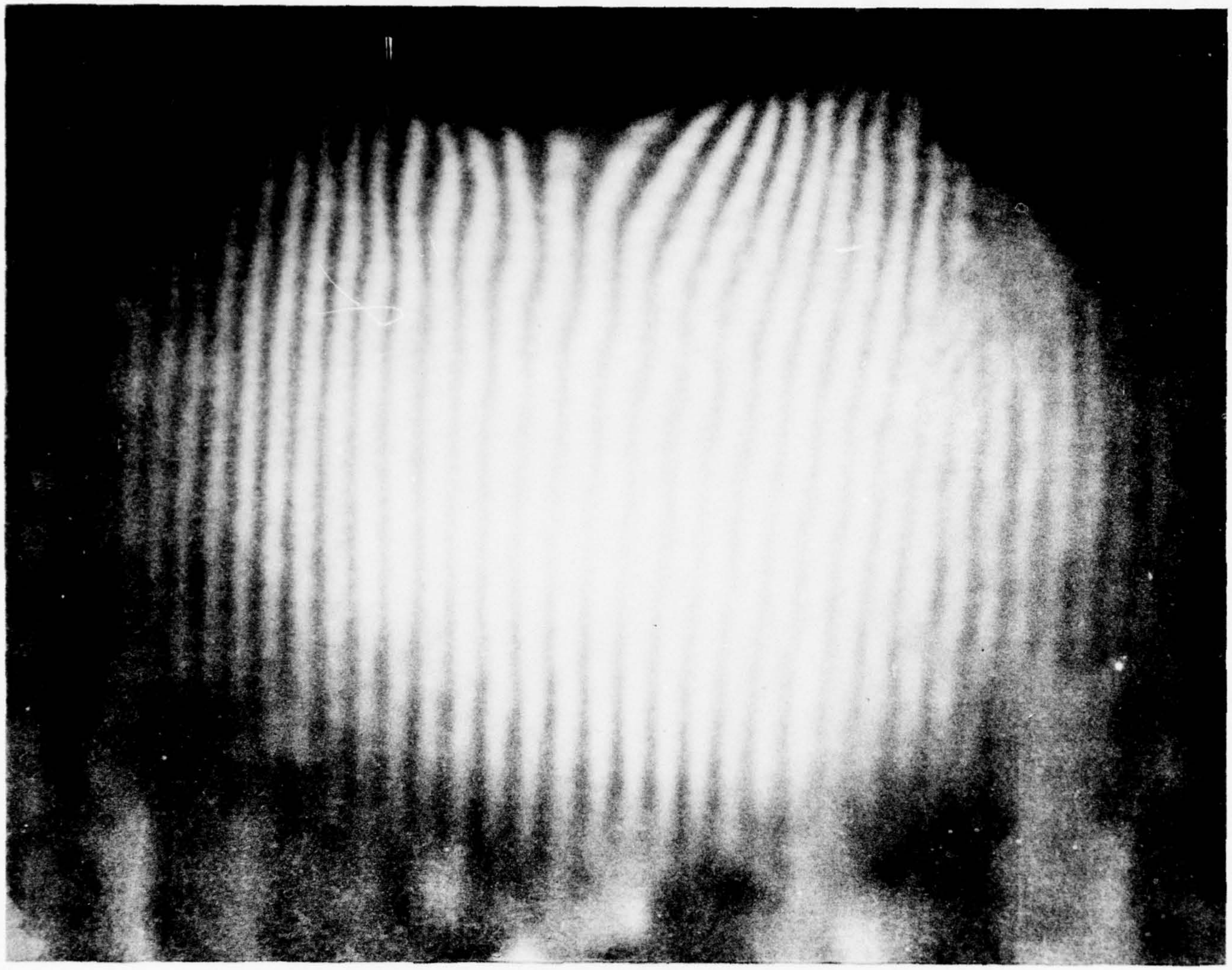

FIGURE 15. Ann Arbor Distortion Test with XM-29 Mask Oriented at 45° Left Angle

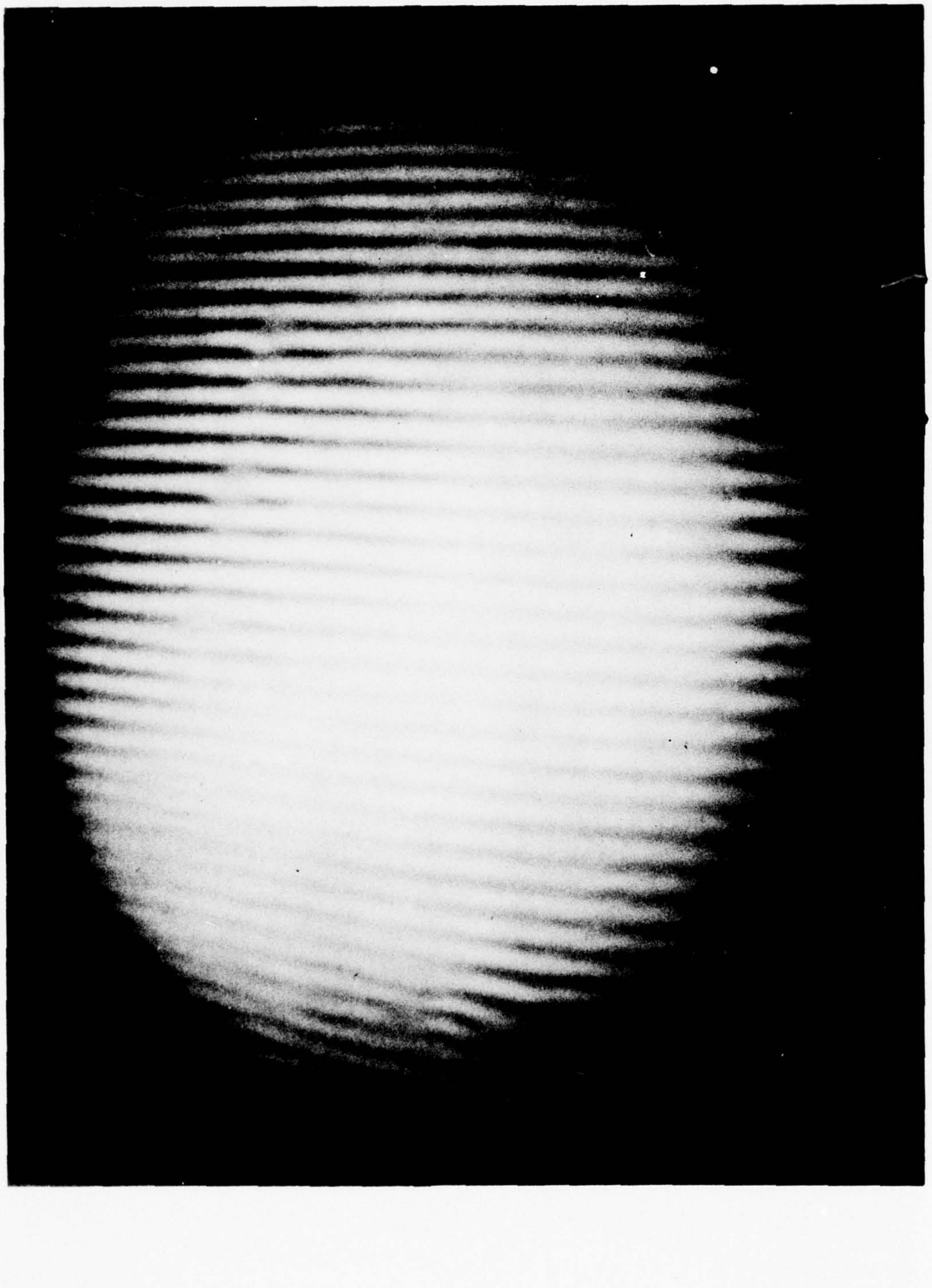

FIGURE 16. ANN ARBOR DISTORTION TESTER WITH M-24 MASK ORIENTED AT 45° RIGHT ANGLE

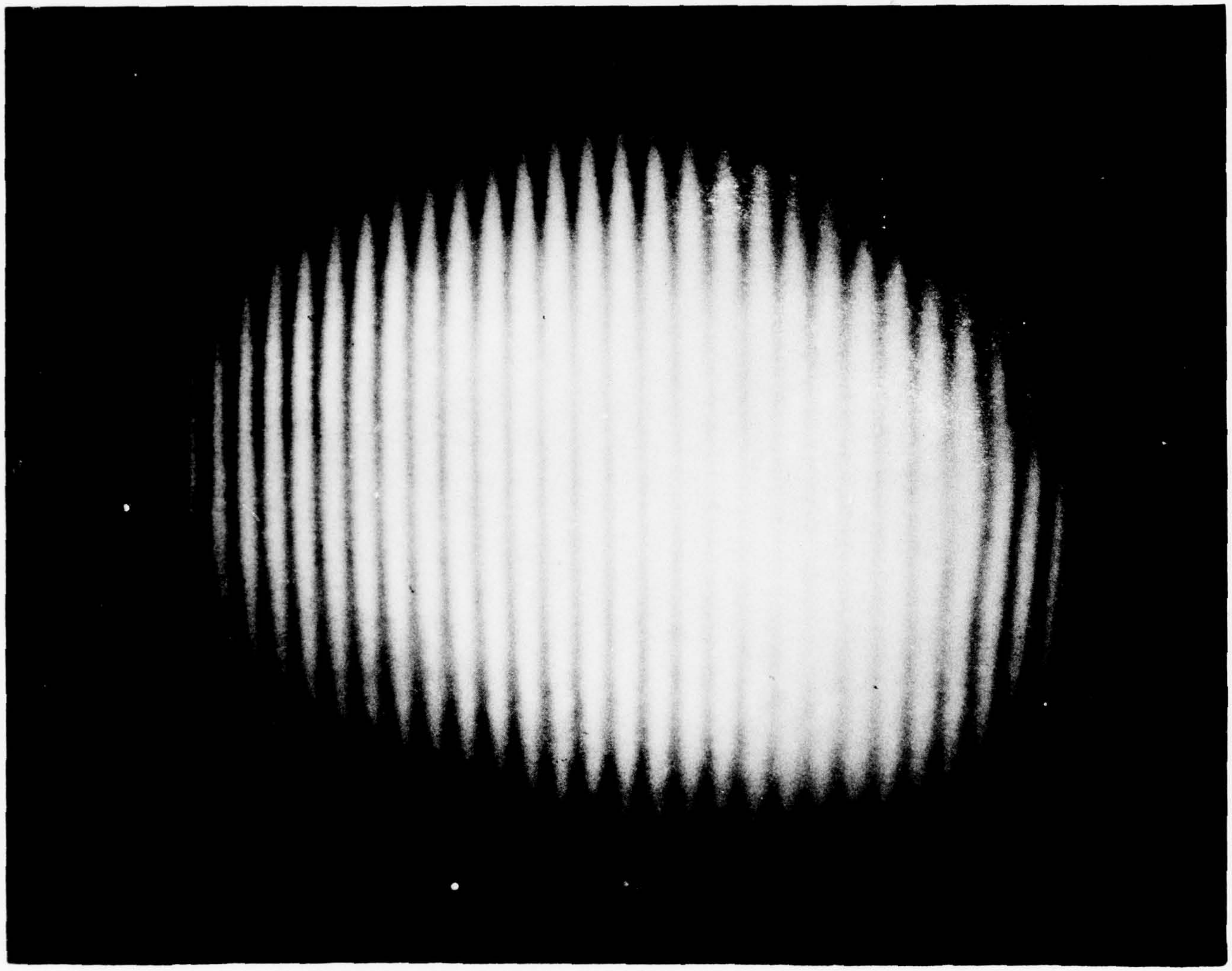

FIGURE 17. ANN ARBOR DISTORTION TESTER WITH M-24 MASK ORIENTED AT CENTER

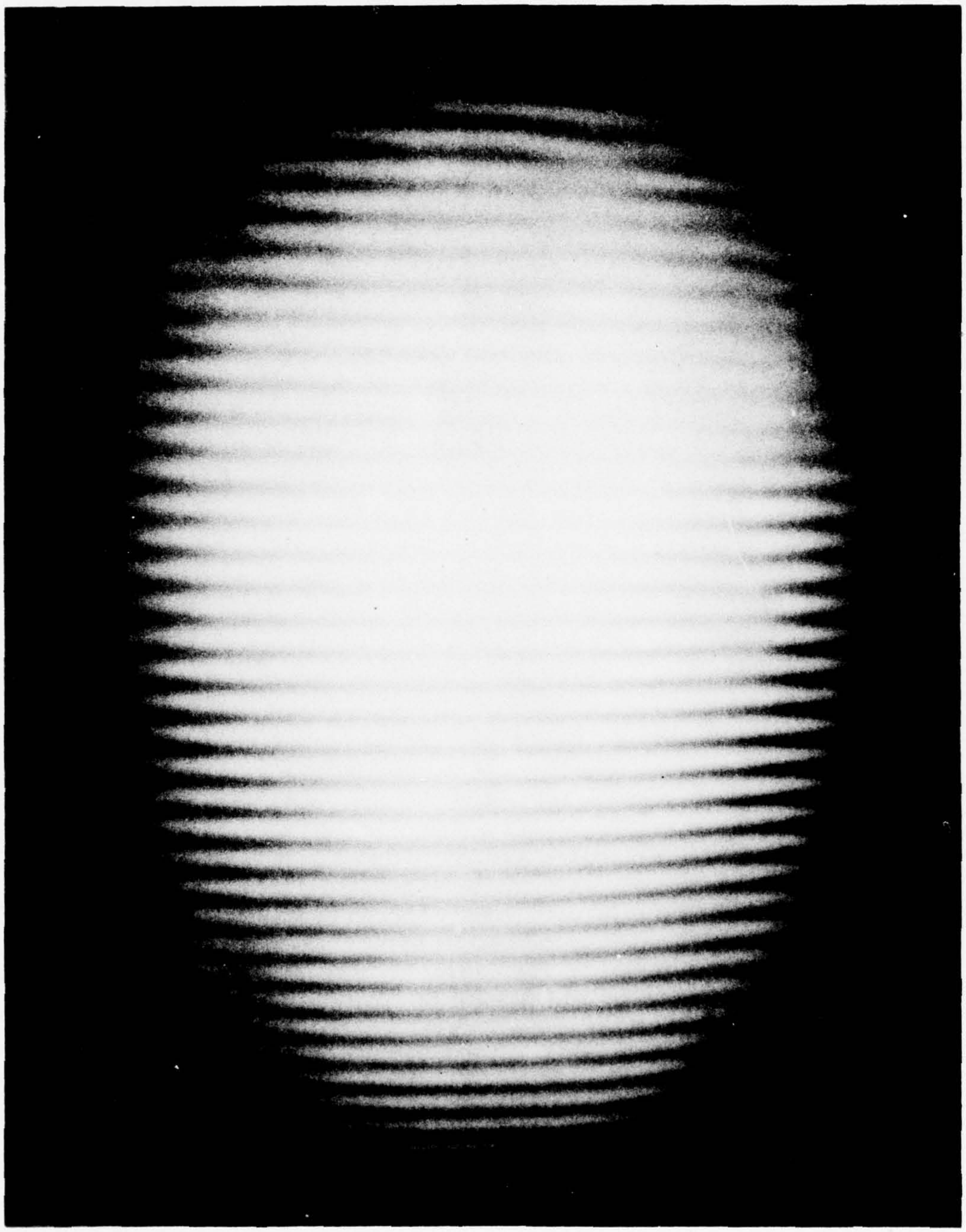

FIGURE 18. ANN ARBOR DISTORTION TESTER WITH M-24 MASK ORIENTED AT 45° LEFT ANGLE

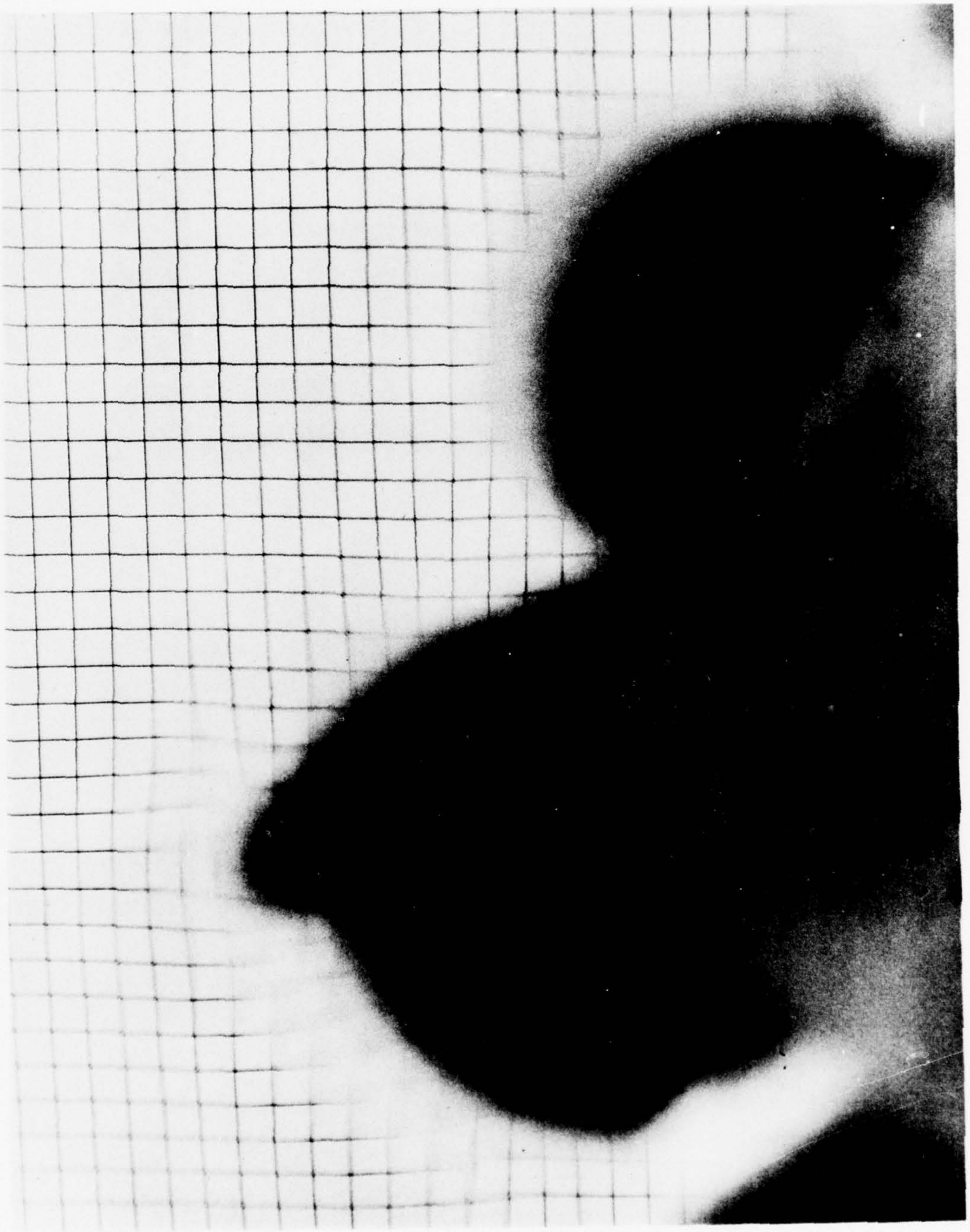

FIGURE 19. XM-29 Mask Distortion Test Against 1.8 cm Grid Board at Distance 90 cm With Mask Oriented 45° to the Left

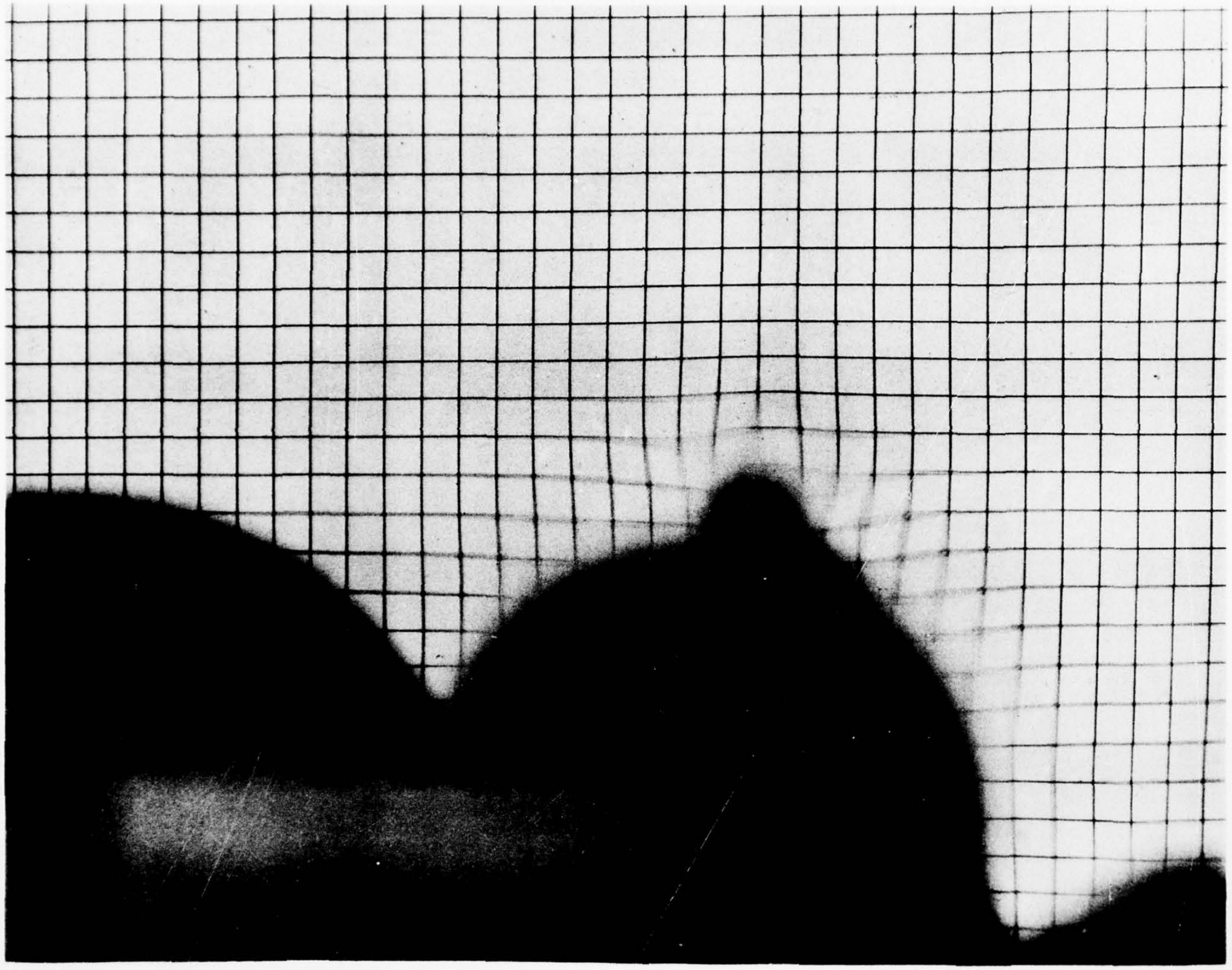

FIGURE 20. XM-29 Mask Distortion Test Against 1.8 cm Grid Board at Distance 90° cm With Mask Oriented 45° to the Right

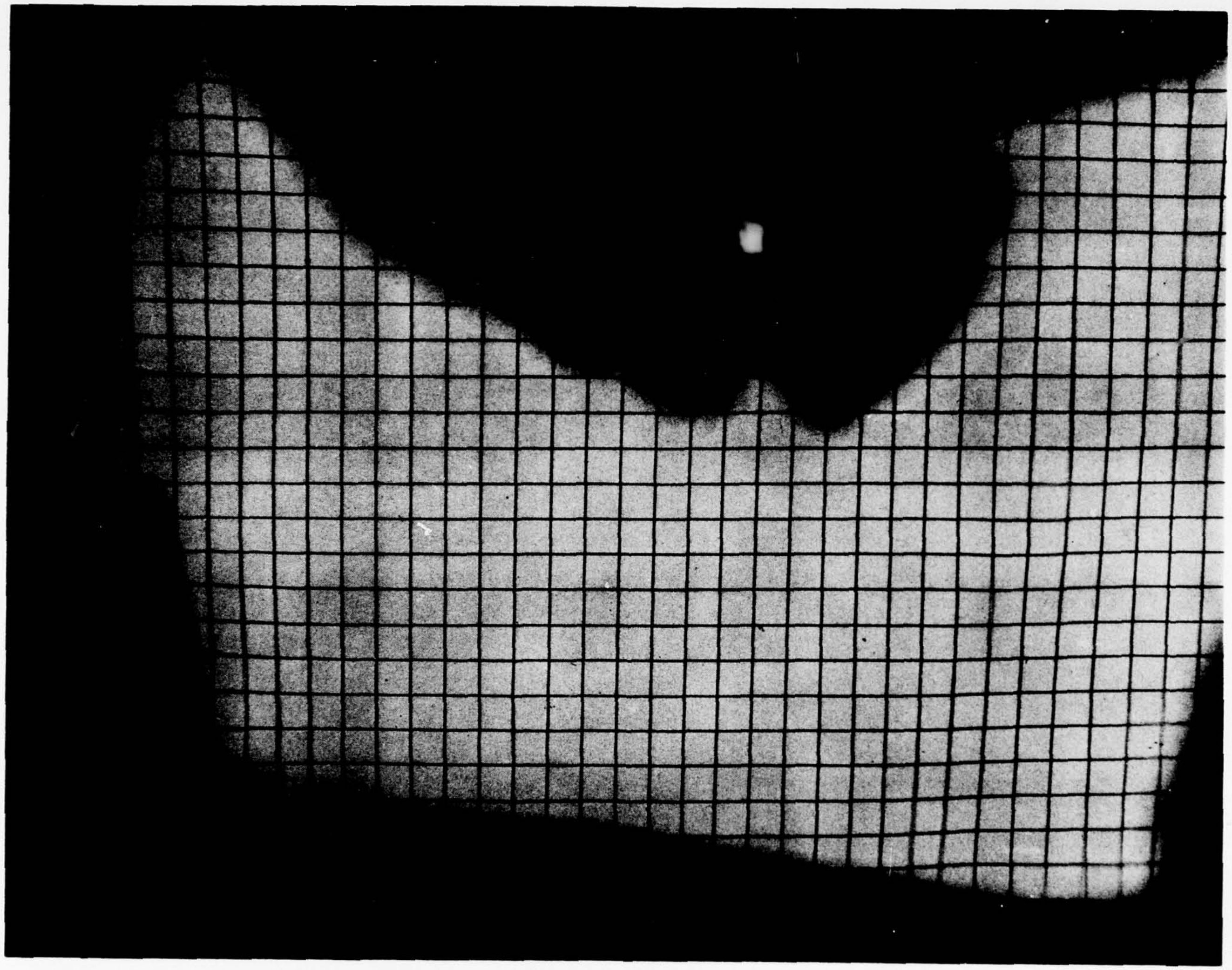

FIGURE 21. M-24 Distortion Test Against 1.8 cm Grid Board at Distance 90 cm With Mask Oriented at 45° Right Angle

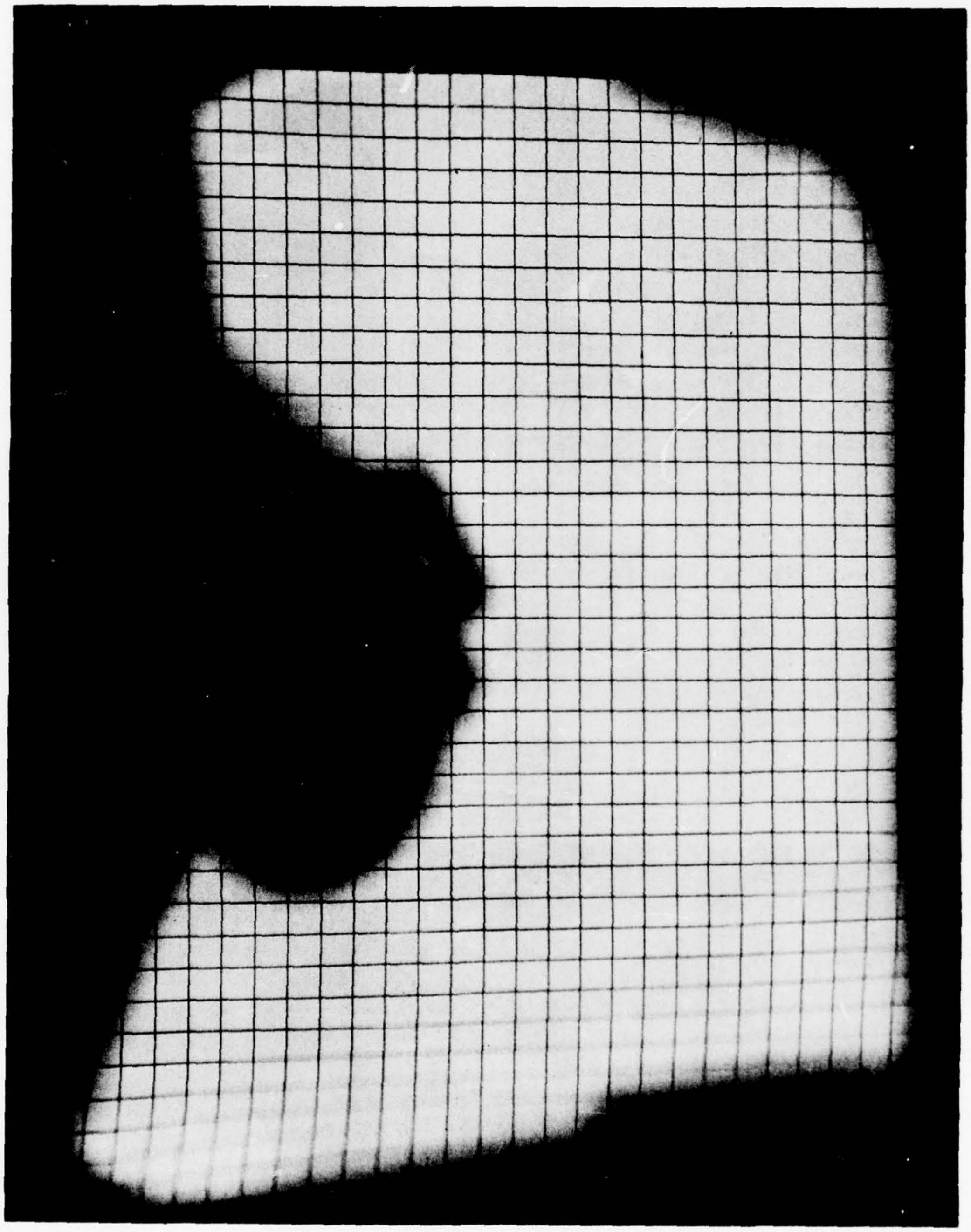

FIGURE 22. M-24 Distortion Test Against 1.8 cm Grid Board at Distance 90 cm With Mask Oriented at 45° Left Angle

c. Results. Figures 19 through 22 show the results from the ASTM metric grid board tester. Unfortunately, an acceptable quantitative method of analysis is still unavailable with this technique at the present time. The only criterion for the standard is qualitative subjective inspection and comparison performed by an experienced observer. The distortion test result of the XM-29 sample shown in Figure 19 indicates very severe optical distortion around the nose-cup region. A similar degree of impairment occurs in Figure 20 for the 45° right hand side orientation of the XM-29 protective mask. In contrast the M-24 sample revealed very little distortion as shown by the photographic documentation in Figures 21 and 22. Only a slight linear displacement occurs at the peripheral portion of the sample.

B. Visual Analyses

1. Visual Field

a. Apparatus. Visual field testing was performed with an Aimark Projection Perimeter, manufactured by U.K. Optical Bausch and Lomb Ltd. The projected target stimulus consisted of a 3 mm white light moved along the arc of the perimeter which was centered at a distance of 33 cm from the eye being tested. The luminance of the target stimulus was 12 footlamberts and the luminance of the arc was approximately 5 footlamberts.

b. Method. Standard clinical procedures were used to obtain the visual field measurements. As with all of the psychophysical testing, three subjects were used, each making the observations under the three viewing conditions: no mask, wearing XM-29 mask, wearing M-24 mask. Since monocular fields were desired, the tested eye was carefully centered in the apparatus and the fellow eye was occluded. The observer was instructed to tap when he detected the white target moving in from the periphery while carefully maintaining fixation on a central fixation point. The target was slowly moved in from the extreme periphery at a constant velocity until it was reported as being seen. Eight visual field meridians were tested in this manner, and each meridian was retested to insure accuracy. The subject was then re-positioned and the companion eye was tested. Each subject participated in three sessions on separate days to allow measurements with all viewing conditions.

c. Results. Figure 23 displays the average results from the observers for the three viewing conditions. As shown in this figure, the two monocular visual fields were combined to present the total visual field for each viewing condition. The visual field allowed with the XM-29 mask is much larger than that measured while wearing the M-24

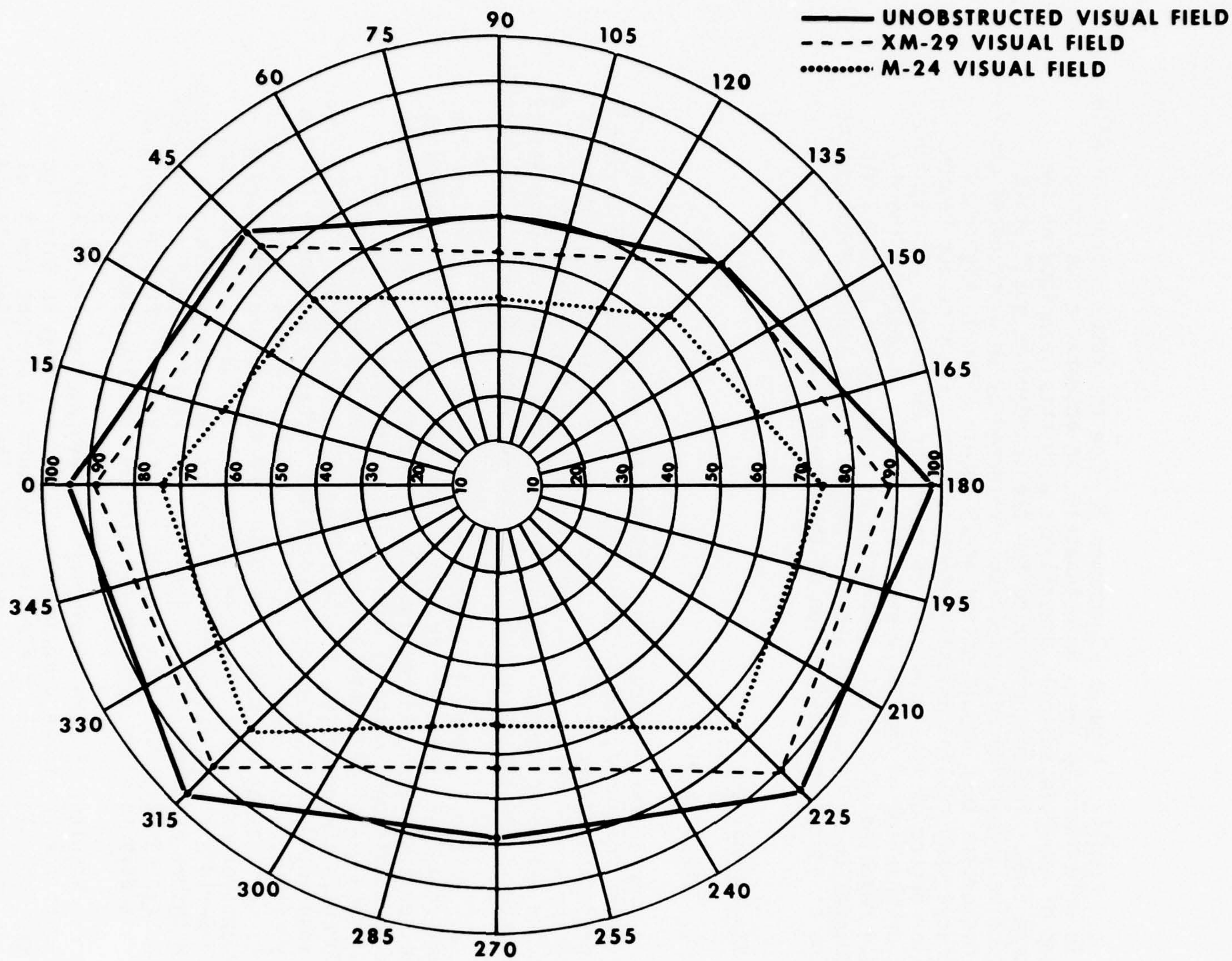

FIGURE 23. VISUAL FIELD

mask. Geometric analysis indicates that the XM-29 only reduces the visual field by 17% from unobstructed viewing. However, the M-24 causes a 42% reduction in the field from the unobstructed field.

2. Dynamic Visual Acuity

a. Apparatus. The resolution targets consisted of Landolt rings of standard proportion. A series of sizes prepared as high contrast (95%-98%) 35 mm slides were available. These were projected using a Kodak Model No. RA-950 random access projector with a 5" focal length lens whose aperture was reduced to 3 mm for improved definition and depth of focus. A dove prism in the beam permitted the location of the gap in the Landolt ring to be varied. Chromatic fringes produced by the prism were eliminated by isolating the green portion of the spectrum with a Wratten #61 filter. Movement of the targets was accomplished by a General Scanning Model G-330PDT Optical Scanner and Model CCX-102-3T Scanner Driver. The input signal was a linear ramp voltage generated by a USAARL-built programmed function generator. The Landolt ring slides were ultimately projected upon a Polacoat rear projection screen of 16" horizontal width. From the observer's position, 36" from the screen, the target critical details ranged in angular subtense from 11'15" to 1'18". Target velocity throughout was 53.5°/s. Target luminance averaged 20.8 footlamberts.

b. Method. Each of the three observers participated in three sessions. In each session, they received eight "warm up" trials followed by 28 trials in each condition: no mask, XM-29, M-24. The order of the three conditions was varied from session to session and from observer to observer so that order effects were completely counterbalanced. Using the psychophysical method of constant stimuli, each 28 trial block contained four presentations of seven target sizes. On half of the presentations, target movement was from left to right, on half, the reverse. Both target size and direction for each trial was determined following a constrained random ordering. The gap in the Landolt ring could appear in any of four positions: upper left, upper right, lower left, and lower right. The observers indicated their response by pressing the appropriate one of four available switches. If the interior of the mask began to fog, testing was suspended. The results for the three sessions were pooled yielding a single psychometric function for each mask condition. From the psychometric functions, the angular sizes of the Landolt ring gaps which were detected correctly 90% and 95% of the time, were determined by linear interpolation.

c. Results. The average angular sizes of the gap which were detected at the 90% and 95% criteria for the three mask conditions are depicted graphically in Figure 24. It may be seen that performance was

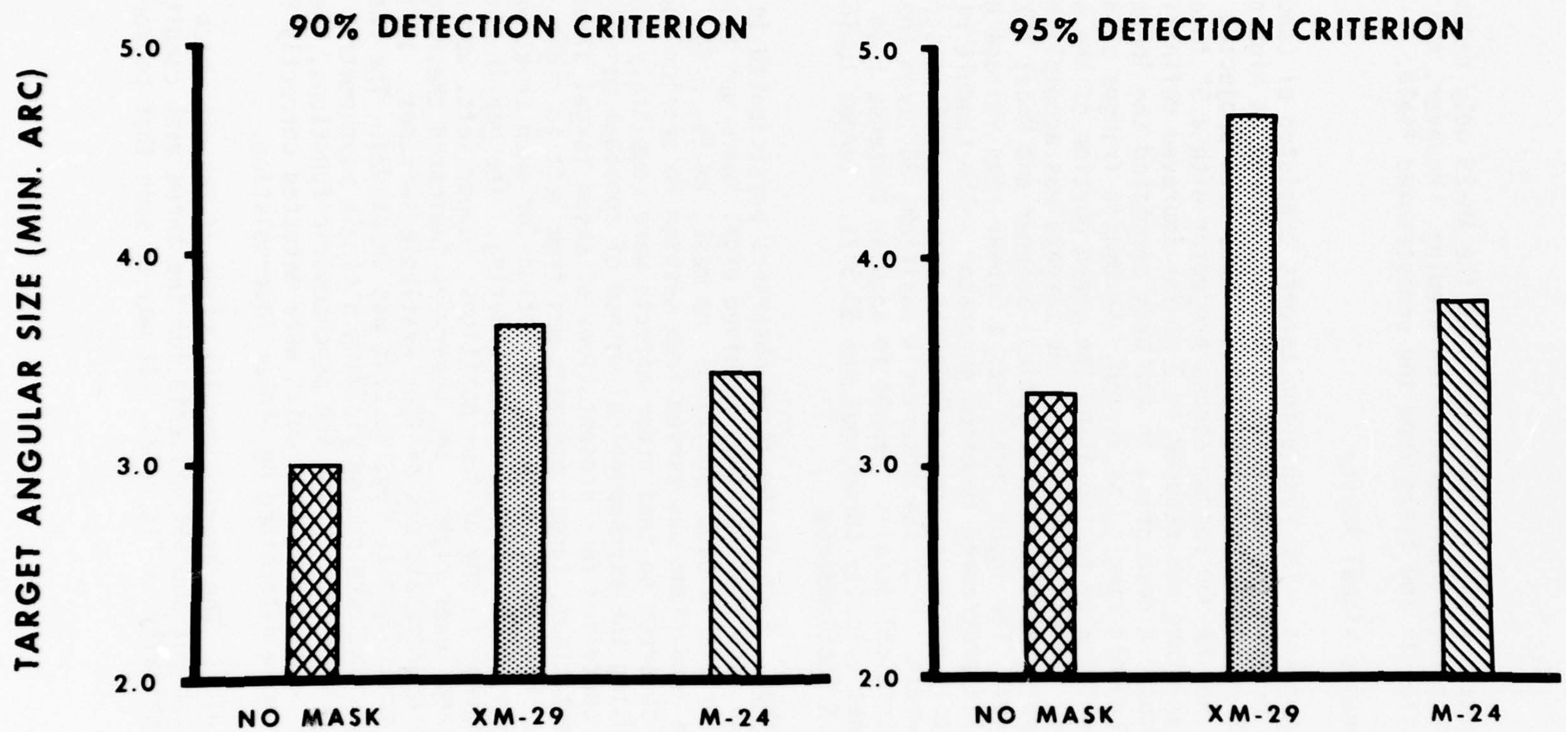

FIGURE 24. DYNAMIC VISUAL ACUITY

poorest with the XM-29, somewhat better with the M-24, and best with no mask. The differences in thresholds among mask conditions were statistically significant ($F=7.27$, $df=2/4$, $p<.05$) when evaluated by a Treatments x Treatments x Ss ANOVA.

3. Stereo-Acuity

a. Apparatus. Stereo-acuity is a measure of an observer's ability to determine relative depth differences based upon retinal image disparity information from the two eyes. For these tests a modified Howard-Dolman apparatus was used. Thresholds are determined by an observer's ability to align two vertical rods, one movable and one fixed, into a frontoparallel plane at some fixed viewing distance (6 meters in the present investigation). Modifications to the basic instrument consisted of driving the variable vertical rod by a motor which was controlled by a radiofrequency receiver. The observers held a transmitter and moved a toggle switch in a fore and aft direction to elicit rod movement and effect alignment with the fixed comparison rod. When an observer indicated alignment of the two rods, displacement readings (i.e., deviations from exact alignment were taken to the nearest 0.1 mm with a digital voltmeter which read the voltage across a linear potentiometer attached to the variable rod. Except for a 0.75° x 1.75° viewing window in the front of the instrument, the apparatus was completely enclosed and illuminated with electroluminescent panels lining the sides and top of the case. The luminance level of the instrument was 6.70 footlamberts.

b. Method. Each of the three subjects viewed the test apparatus under three observation conditions (no mask, through the XM-29 mask, through the M-24 mask) and four angles of view (center, left, right, down center). The particular order of viewing condition x viewing angle was varied according to a random schedule within and between subjects so that the measurements were counterbalanced. Multiple sessions, each lasting approximately 45 minutes, were necessary for all subjects. The method of adjustment was the psychophysical procedure chosen for these measurements, and ten determinations were made for each viewing condition by all subjects. Several additional precautions were taken to guard against observer experimental bias errors. The velocity of the variable rod was randomly changed to prevent a subject from using time as a factor in achieving equality. Also, when the observer had indicated equality of distance for the two rods, the lights in the apparatus were extinguished and the experimenter moved the variable rod to either the front or back of the instrument on a pre-determined schedule prior to initiating the next trial.

c. Results. Hirsch and Weymouth[3] have previously discussed the theoretical implications of measures of depth discrimination thresholds, and their suggestion of using the standard deviation of the linear displacement scores has been adopted by other investigators in subsequent reports. Accordingly, our measure of threshold was the standard deviation of the displacement scores from the ten observations made by

each observer under the different viewing conditions. Table 9 shows the average thresholds obtained from the three observers with the three viewing conditions and four viewing angles at six meters.

TABLE 9, STEREO-ACUITY THRESHOLDS WITH HOWARD-DOLMAN APPARATUS

ANGLE OF REGARD	VIEWING CONDITION	LINEAR THRESHOLD (CENTIMETERS)	ANGULAR THRESHOLD (SECONDS OF ARC)
Center (Primary)	No mask	1.8	6.8
	XM-29	2.4	8.8
	M-24	1.9	6.8
Left	No mask	2.0	7.4
	XM-29	2.5	9.4
	M-24	2.3	8.4
Right	No mask	1.7	6.4
	XM-29	1.9	7.0
	M-24	2.7	10.1
Down Center	No mask	2.0	7.3
	XM-29	3.1	11.3
	M-24	3.5	13.0

As shown in this table, unobstructed viewing yielded lower thresholds for all viewing angles. However, the differences for any of the thresholds at any viewing angle are not considered perceptually significant for the performance of most military tasks.

Angular disparity thresholds corresponding to the linear displacement thresholds are also shown in Table 9. These were determined using the following equation:

$$\eta = \frac{a\ (\Delta d)}{d^2} \cdot 206{,}280$$

where

η = angular threshold in seconds of arc
a = interpupillary distance
Δd = linear displacement of the variable rod from the fixed rod
d = observation distance.

Binocular thresholds of 5 to 8 seconds of arc for unobstructed viewing have been reported previously in investigations[3,4] in which equivalent testing procedures were used.

4. Visual Modulation Transfer Function

a. Apparatus. The display unit consisted of a Conrac Model QQA/17 TV monitor. The sync and blanking signals were provided by a Visual Information Institute model 311 sync generator and the pattern information was provided by a Tektronix model 502 function generator. The signal from the function generator was connected to a potentiometer controlled by the subject and this signal plus the output of the sync generator went to a Visual Information Institute model 404 pedestal generator. The signal from the pedestal generator drove the monitor and the signal from the potentiometer was read by a Hewlett-Packard Model 3469B AC voltmeter. The output from the voltmeter and the frequency information from the function generator went to a Digitic model 6150 printer. The display on the monitor was scanned by a Photo Research Model 1980 Photometer mounted on a Velmex Unislide translation bed and the brightness information was recorded graphically on a Hewlett-Packard model 7100BM recorder. A schematic of the system is shown in Figure 25.

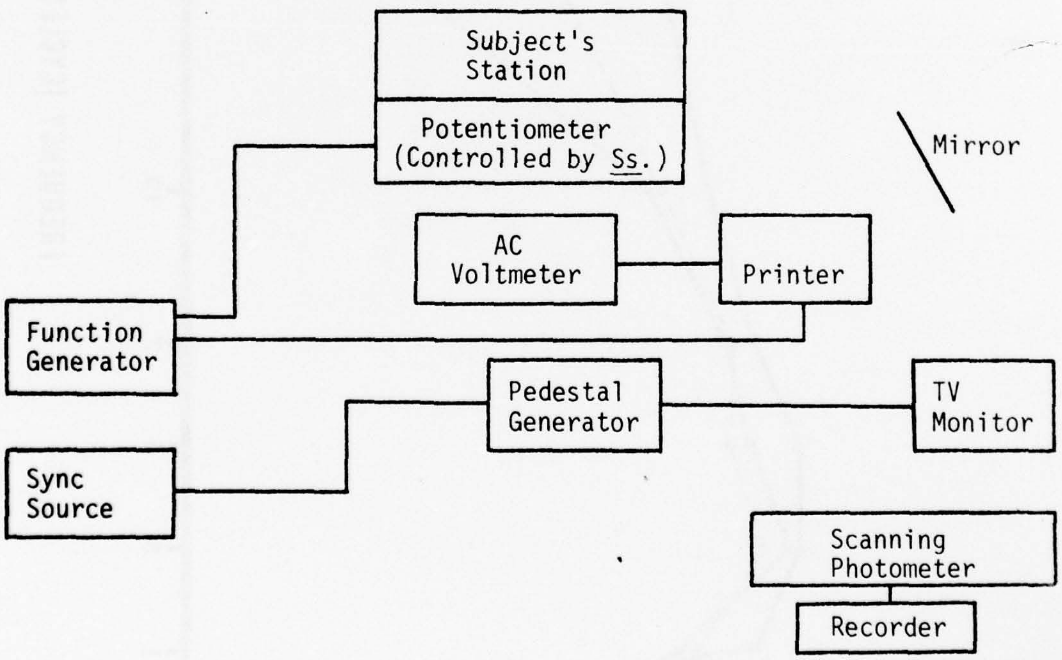

FIGURE 25. SCHEMATIC OF VMTF APPARATUS

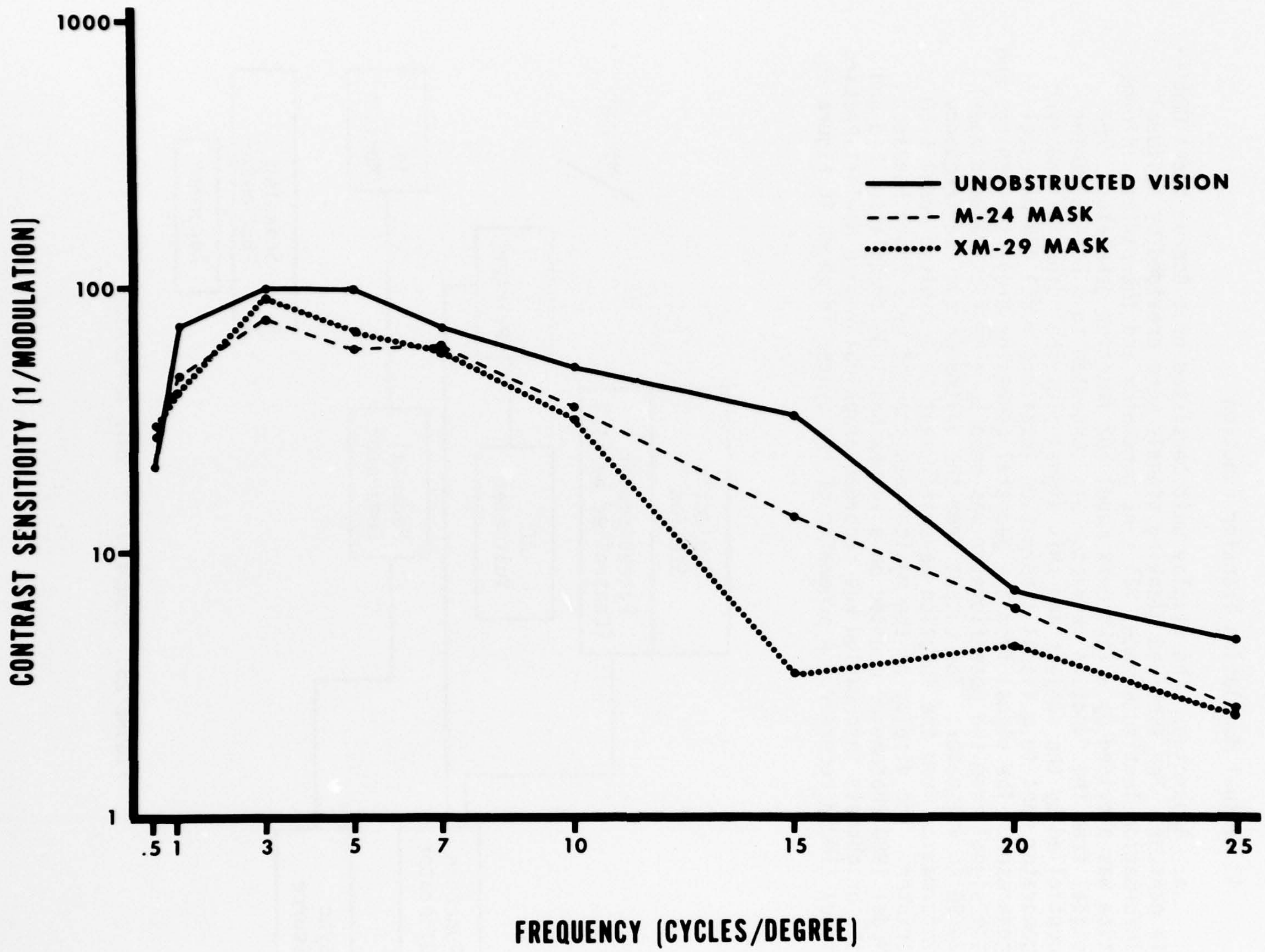

FIGURE 26. VISUAL MODULATION TRANSFER FUNCTION

The observers were the same three males used in the other studies in this report.

b. Method. The observers were seated in front of the monitor at a viewing distance of 9.25 feet. It was explained to them that sinusoidal bars of varying widths would be appearing on the monitor and that their task was to turn the potentiometer clockwise (ascending trials) until the bars could just be seen or turn the potentiometer counter-clockwise (descending trials) until the bars just disappeared. Each subject was given two ascending and two descending trials per session at each of the following spatial frequencies: .5, 1, 3, 5, 7, 10, 15, 20, and 25 cycles/degree visual angle. Each subject received two sessions with no mask, two sessions with the M-24 mask, and two sessions with the XM-29 mask. Sessions were counterbalanced in the manner ABCCBA.

The subjects' settings (AC voltmeter readings) were recorded after each trial and at the end of a session the scanning photometer was used to determine the peak and trough brightness corresponding to each setting.

c. Results. Figure 26 shows the contrast sensitivity as a function of spatial frequency for each of the three viewing conditions. The results are averaged over the three subjects. Contrast sensitivity is defined as $\frac{B\ max - B\ min}{B\ max + B\ min}$ where B max = the peak brightness of a cycle and B min = the trough brightness of a cycle. It can be seen that at all frequencies except the lowest the no mask condition is superior to either of the mask conditions. It can also be seen that at all frequencies above 5 cycles/degree the M-24 mask is superior to the XM-29 mask. This is in line with results of another test which showed that the XM-29 mask scatters more light than does the M-24. This scattering effect would be expected to affect the high frequencies more so than lower frequencies.

5. Dark Adaptation

a. Apparatus. A Goldmann/Weekers Adaptometer, manufactured by Haag-Streit Company, was used for the measurement of dark adaptation. This instrument consists of an integrating sphere used for pre-adaptation, a fixation light to control the location of the retinal area tested, a stimulus light of variable intensity, and an automated recording device. The test stimulus consisted of a white circular light subtending 10° and it was presented 11° below the fixation point.

b. Method. Dark adaptation curves were obtained on each of the three observers with three different viewing conditions: no mask,

wearing XM-29 mask, wearing M-24 mask. The viewing conditions were counterbalanced between observers to reduce order effects. Each observer participated in three sessions, each lasting approximately 45 minutes.

After the observer was familiarized with the instrument and the observations required of him, the lights in the experimental room were extinguished and he was positioned into the apparatus. He was then exposed to a bleaching light of 424 footlamberts for a period of 5 minutes. The bleaching light was then turned off, and the testing procedure was initiated. The intensity of the test stimulus, originally below detection threshold, was gradually increased, and the observer, while steadily viewing the fixation light, actuated the recording device as soon as he detected the test stimulus. When this occurred, the experimenter immediately reduced the intensity of the test stimulus. Following a one minute interval, the intensity of the test stimulus was again increased, and the procedure was repeated. This cycle was continued for 40 minutes.

c. Results. Since the measure of interest in these observations was the final visual sensitivity achieved with the various viewing conditions, only the thresholds obtained in the last 10 minutes of testing (i.e,. 31 to 40 minutes following the bleaching light) are reported. The thresholds obtained during this time are considered reasonably stable and final, and the data points were averaged to present a representative threshold value. This was done with the results obtained from each observer using each of the three viewing conditions. The results are shown in Table 10. The thresholds shown in this table are the average sensitivity levels determined from the three

TABLE 10. DARK ADAPTATION THRESHOLDS

Viewing Condition	Threshold
Unobstructed Viewing	4.85×10^{-5}
XM-29	2.97×10^{-4}
M-24	3.58×10^{-4}

observers. As shown in Table 10, visual sensitivity thresholds obtained while wearing the XM-29 and M-24 mask were equivalent. However, both masks caused an approximate loss or degradation in visual sensitivity of approximately 1 log unit. These measures of reduced sensitivity are considered conservative because of the relatively gross stimulus target size (10°). Smaller target sizes, with more discrete retinal areas tested, would probably have evoked larger differences in masked versus unobstructed viewing thresholds.

6. Color Vision

a. Apparatus. Standard clinical tests were used to evaluate color vision while wearing the XM-29 and M-24 masks. These were the Dvorine Pseudoisochromatic Plates, the Farnsworth Projection Lantern, and the Farnsworth D-15 test. The Dvorine test and the D-15 test were performed while the color samples were illuminated by a Macbeth Daylight Lamp.

b. Method. Each of the three subjects completed all testing during a single session. After initial testing to insure that the subject had normal color vision, the tests were repeated while the subject wore the XM-29 and M-24 masks. To insure validity, the methods of test administration prescribed by the manufacturers were precisely followed.

c. Results. None of the three subjects tested demonstrated any deviation from normal color vision while wearing either of the protective masks. This indicates that the spectral transmission characteristics of both masks are sufficiently acceptable to allow normal perception of colors while wearing the masks.

DISCUSSION

Deficiencies of present mask systems noted in the ROC for the development of the XM-29 mask included hindrance of normal vision and the use of optical instruments with masks use since unimpaired vision is a recognized requirement in a military environment. Therefore, one of the central goals in the developmental mask was supposedly to improve the visual capability while wearing a protective mask. The essential characterisitcs of the XM-29 mask relative to vision are stated in paragraph 5.d. of the ROC:

> "Vision: The mask shall permit unobstructed and undistorted forward vision. Peripheral vision shall be not less than that required by Army aviators, and will meet the guidelines on field of vision for aircrewmen as developed by the U.S. Army Aeromedical Research Laboratory. The lenses shall be shatter and glare resistant. The mask shall allow the wearing of corrective spectacles or should provide a simple system of corrective optical inserts compatible with military spectacle lens to be in use in the FY 83 time period, and shall allow the satisfactory use of common standard optical devices such as binoculars, BC scopes, night vision devices, individual weapon sights, crew served weapons, and combat vehicle weapons systems, etc."

Since the essential characteristics are qualitative, the quantitative specifications relevant to visual and optical standards published for the M-17 and M-24 protective masks have been used in the analysis of the present results whenever possible.

Table 11 presents a comparison of the visual and optical tests completed with the XM-29 and M-24 protective masks. It is obvious from this table that the XM-29 has failed to provide an improved visual capability from that provided with the M-24 mask. Of 13 tests performed, the new XM-29 mask is inferior to the standard M-24 mask on eight tests. It provides equivalent performance on four tests, and the new mask is superior in allowing a larger visual field when worn. The basis of comparison, the optics of the M-24 mask, should be briefly considered. The lens in this mask consists of a semi-flexible material constructed from polyvinyl chloride. Some surface blemishes were readily apparent upon casual inspection. The lenses in the M-17 mask are fabricated from rigid CR-39 material which is widely used to provide ophthalmic lenses of excellent quality. Although it was not evaluated, it is suspected that optical and visual performance with the M-17 would be better than the M-24, and, therefore, even more superior to the new XM-29 protective mask.

TABLE 11
COMPARISON OF VISUAL/OPTICAL CHARACTERISTICS
OF XM-29 WITH M-24 MASK

	XM-29 is:
Spherical & Cylindrical Power	Inferior
Prismatic Power	Inferior
Lens Distortion	Inferior
Image Fidelity	Inferior
Spectral Transmission	Same
Average Light Transmission	Inferior
Haze	Inferior
Stereo-Acuity	Same
Color Vision	Same
Visual Field	Superior
Dynamic Visual Acuity	Inferior
Visual Modulation Transfer Function	Inferior
Dark Adaptation	Same

Some of the tests here reported were inter-related and there was a presumed cause and effect which contributed to the results. For example, the image fidelity test measured with the Ann Arbor Tester revealed that

the optical quality of the XM-29 mask was very poor. Also, the measured haze of the material was excessive. Both of these results could be caused by surface defects of the coating, surface defects of the base silicone material, or defects embedded in the silicone matrix. Any particular one of these three possible causes cannot be isolated with the present investigation, but it is quite possible that all contribute to some degree.

Regardless of the cause, the visual impact of both poor image fidelity and excessive haze is in the reduced definition of the transmitted image. Visual acuity through the mask will be reduced, particularly targets which are initially of low contrast. An indication of this is shown in Figure 26 which displays a visual modulation transfer function. This figure shows that the contrast must be increased (i.e. decreased contrast sensitivity) in order to resolve targets composed of higher spatial frequencies while wearing the XM-29 mask.

As indicated in the previous section of this report, spectral transmittance and chromaticity of the new mask are adequate. The visible light transmitted through the mask is reasonably independent of wavelength so that the total visible spectrum is approximately flat or neutral. This is supported by the color testing which showed that observers wearing the XM-29 still retained normal color vision. However, the <u>average</u> light transmission was inadequate (Table 4). The specifications for existing masks require a value of 89% transmission while the working goal for the XM-29 has been 85%. A measured value of 83% is below this goal. While the 1 log unit lowered light sensitivity measured in the dark adaptometry tests (Table 10) gives some indication of the problems that might be caused by this poor light transmittance property, the impact on field military effectivity can be very considerable. Field performance with the mask will be most affected by this during periods of reduced illumination such as twilight or night. At present, a large emphasis is being made toward continuous around-the-clock military operations. To fulfill this requirement, many changes in tactics and training plans have been developed for night operations. However, the XM-29 mask would degrade visual sensitivity at night. A 1 log unit reduction in sensitivity corresponds to the change in general illumination level due to a 25% change in the moon phase (e.g., 1/2 to 1/4 moon). Not only would apparent brightness and detectable information content of images transmitted through the mask be reduced, but also the visual system might be changed from photopic or mesopic functioning to the scotopic (rod) system which is notably ineffective in processing precise visual information. The reduced average light transmittance of the XM-29 is additionally unacceptable in consideration of all existing masks in the inventory which have, and are required to have, better light transmittance than that measured for the prototype mask. Also, several new optical transparency materials have been developed which yield transmittance values in excess of 92%.

The measured sphero-cylinder powers (Table 2) of the XM-29 mask exceed the specification published for the M-17, while the M-24 mask falls within that specification. As noted previously, these measures are conservative because of placement of the mask and should be expected to increase when the mask is placed in the normal wearing position. These undesirable refractive powers would result in focus errors, especially with the cylindrical component, and also would cause ocular discomfort if the mask were to be worn for an extended period of time. The measured prismatic power (Table 1) also exceed the maximum allowable limits published in the M-17 specification and could also seriously degrade visual functioning. The prismatic power alters the normal vergence of the incident light and thereby changes the convergence demand of the oculomotor system. This would upset the delicate ratio balance of the accommodative and convergence components of the visual system resulting in ocular distress and visual inefficiency. The deviation of the light path caused by the prism could also result in errors in space perception. An indication of the space distortion is apparent in the lens distortion photographs (Figures 19 and 20). Errors in the perception of space and distance would be disastrous in tasks requiring good depth discrimination, e.g. jumping barriers, operating motor vehicles, flying aircraft. Measures of stereo-acuity (Table 9) might be expected to reflect upon the problems caused by the prism. While the stereo thresholds were reduced while wearing the mask, the measured changes are not considered to be perceptually significant but only an indication that something is causing visual degradation. It should be understood that these measurements were obtained under a rather static situation involving reduced visual cues which were carefully controlled. Only small, discrete areas of the mask (and retina) were used for any particular measurements. Errors in space perception which have been discussed above usually involve a much larger portion of the visual field and should be measured in a leaf room or with a space eikonometer. Since there have been reports of serious space perceptual errors while wearing the XM-29 mask, a separate contract has been negotiated with a major university to study this problem, and their informal reports to data confirm suspicions that space perception is significantly altered while wearing the XM-29 mask.

The reduced performance in the dynamic visual acuity task (Figure 24) obtained with both protective masks, but particularly with the XM-29 mask, can be considered to be inherent in the mask and not due to a temporary condition such as fogging or unclean surfaces. While not specifically evaluated, it is felt to be unlikely that this performance loss can be attributed to the discomfort and distraction caused by wearing the mask, per se. In performing the DVA task, the observer was required to detect the appearance of the target in peripheral vision (since he did not know in advance the direction of movement and, hence,

at which side of the screen the target would first appear), make the appropriate saccadic eye movment to "catch" the rapidly moving target, and then make the correct velocity pursuit movement to maintain the target in good registry on the fovea of the eye. All this occurred during an exposure time of 470 milliseconds. Because of this transient target presentation, it is obvious that it was impossible for the observer - given the highly varying levels of haze, distortion, prismatic and cylindrical power over the lens surface - to optimize visibility by varying the angle of gaze. In static tasks, an observer could be expected to optimize. However, in actual dynamic use, e.g., an aviator participating in low level flight, the observer responds to transient visual inputs for, especially, obstacle avoidance.

As stated earlier in this report, the purpose of this investigation was to determine if the goal of improving visual performance while wearing a protective mask had been achieved with the development of the XM-29. The results reported here force a negative response. In fact, the results have shown that visual performance is poorer with the XM-29 mask than the mask presently in the inventory. Obviously, a satisfactory optical design has not been developed with the XM-29 in its present configuration. Table 12 is a summary listing of the optical and visual tests performed. As shown in this table, the various tests have been divided into three categories: acceptable, marginal, and unacceptable. While probably self-explanatory, the marginal classification might require additional comment. Visual and optical performance in these tests were low borderline. Normally, these performance results would be unacceptable. However, depending upon the urgency of the military requirement, they could be considered acceptable as an expedient interim solution. Those items listed in the unacceptable category must be corrected before validation of the new mask.

TABLE 12
SUMMARY OF VISUAL/OPTICAL ANALYSES OF
XM-29 and M-24 PROTECTIVE MASKS

XM-29	M-24
ACCEPTABLE	
Visual Field Color Vision Spectral Transmission	Color Vision Spectral Transmission Image Fidelity Lens Distortion Haze
MARGINAL	
Stereo-Acuity Dynamic Visual Acuity Visual Modulation Transfer Dark Adaptation	Spherical & Cylindrical Power Average Light Transmission Prismatic Deviation Stereo-Acuity Dynamic Visual Acuity Visual Modulation Transfer Dark Adaptation
UNACCEPTABLE	
Spherical & Cylindrical Power Prismatic Deviation Image Fidelity Lens Distortion Haze Average Light Transmission	Visual Field

Several other casual observations which have not been formally investigated should be briefly discussed because they impact on visual performance. On the several occasions in which technical observers have worn the XM-29 mask during flight, the mask has fogged so completely

that it is translucent, and aircraft operation would be impossible while wearing it. This has occurred within 10 minutes after donning the XM-29. Also, the curvatures of the mask allow an external glint signature from almost any sun angle. Therefore, camouflage would be difficult, if not impossible, while wearing the mask, especially if there is any concentration of troops within a small area. Finally, reflections arising from the internal surfaces of the mask must be reduced. These are considerable and can produce a veiling glare further degrading visual performance.

The final question which must be asked is whether the visual and optical deficiencies herein reported can be corrected by simple engineering changes. That question was not addressed in this investigation. However, near term solutions do not appear readily available. The excessive optical powers and aberrations arise from the steep face-form angle of the mask transparency. If they are to be corrected, major changes in the mask curvatures will probably be necessary. The XM-29 mask presents a new application of silicone. If the poor image quality, reduced transparency, and excessive haze are caused by the basic optical properties of this material, its use must be questioned. An improved optical and visual design would include flat optics fabricated from highly transparent, ophthalmic quality material such as quartz-coated CR-39.

CONCLUSIONS

1. While no specifications are yet available for the XM-29 protective mask, the new mask fails to meet any of the optical standards published in MIL-L-0050064E(MU) for the lenses in the M-17 protective mask. The percentage haze, prismatic effects, and refractive powers in the XM-29 mask are excessive, and the light transmission is inadequate.

2. Except for color vision which was normal with both masks tested, visual efficiency was degraded while wearing either the XM-29 or the M-24 masks. However, performance with the new XM-29 mask was poorer on the visual modulation transfer testing and dynamic visual acuity than with the M-24 mask while the degraded performance was approximately equivalent when either mask was worn on the stereo-acuity and dark adaptation tests.

3. The total extent of the visual field allowed with the XM-29 was much improved from that afforded by the M-24 mask, and it compared favorably with unobstructed vision.

RECOMMENDATIONS

1. Independent failure analyses of the XM-29 mask should be conducted. These tests should include chemical and optical analyses of the basic silicone material and optical coating used in fabrication of the mask. Complete optical analysis of the mask curvatures should be conducted to optimize the design and reduce or eliminate the various optical aberrations and refractive errors.

2. The Mask Development Office should reconsider the air flow in the mask to eliminate the problem of excessive fogging when the mask is worn.

3. Development work should be immediately initiated to attempt to reduce or eliminate the problem of external glare and internal reflections with the mask.

4. Since some of the problems identified in the present investigation are quite serious and basic to the design concept, the prototype XM-29 mask should not receive validation until the failure analyses have been completed and design changes have been developed and tested to insure that visual performance has been improved.

REFERENCES

1. Report of Working Group 48 "Optical Properties and Visual Effects of Face Masks," 1977, Committee on Vision, Assembly of Behavioral and Social Sciences, National Research Council, National Academy of Sciences.

2. Chiou, W.C., "Visible Spectral Transmission Characteristics of Windscreens in Army Aircraft," USAARL-LR-75-29-7-8, Mar 75.

3. Hirsch, M.J. and Weymouth, F.W. "Distance Discrimination. I. Theoretic Considerations,", 1948, Archives of Ophthalmology, 39:210-223.

4. Sloan, L.L. and Altman, A. "Factors Involved in Several Tests of Binocular Depth Perception," 1954, Archives of Ophthalmology, 52: 524-544.

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VISUAL AND OPTICAL ANALYSES OF XM-29 AND M-24 PROTECTIVE MASKS by MAJ Roger W. Wiley, O.D., Ph.D.; Isaac Behar, Ph.D.; Wun C. Chiou, Ph.D.; CPT Frank F. Holly, Ph.D.; SP5 Emery R. Spring; SP5 Carol T. Bucha; SP5 Hal Chaikin; and SP4 Carole A. Sherry; 54 pages; 12 tables; 26 figures; DA Project P692000.8190B; Bio-Optics Division

UNCLASSIFIED

1. XM-29 Protective Masks
2. M-24 Protective Mask
3. Optical Testing
4. Visual Testing

USAARL was tasked to provide medical guidance and assessment relative to visual and optical aspects in the development of the XM-29 protective mask. In fulfillment of this responsibility, complete optical and visual tests have been completed on the new mask prior to its validation. To provide baseline and comparison information, identical optical testing was also performed on the M-24 aviator's protective mask, and visual performance testing was completed with the XM-29 mask, the M-24 mask, and unobstructed vision. Of the 13 optical and visual tests used, performance of the XM-29 mask was inferior to the M-24 mask on 8 of them; equivalent performance was obtained with the two masks on 4 tests, while the XM-29 mask was better on 1 test. Several of the optical properties are unacceptable in the present design configuration of the XM-29 mask. Recommendations are made which should be considered prior to validation of a new protective mask.

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